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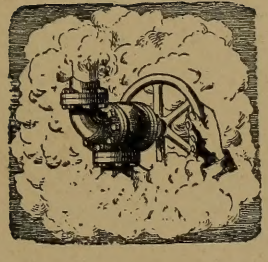

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ACTING VICE-PRESIDENT OF THE WESTINGHOUSE ELECTRIC & MFG. CO., PITTSBURGH

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CASSIER'S MAGAZINE

VOL. XX MAY, 1901 No. 1

NIAGARA FALLS POWER

THE PRESENT EXTENT OF ITS APPLICATION

By Harold W. Buck, Electrical Engineer of the Niagara Falls Power Company

THE POWER AND TRANSFORMER HOUSES OF THE NIAGARA FALLS POWER COMPANY

PROBABLY more has been written about electric power development at Niagara Falls than about any other power plant in the world, partly because it is the largest electric plant in operation, involving remarkable features of hydraulic and electrical engineering, and partly also because the power is furnished by the most famous waterfall in existence. Few, however, are familiar with the remarkable growth, during the past few years, of the industrial system which receives its supply of energy from the Niagara generators, and it is the purpose of this article to outline the many uses to which the power has already been applied and the engineering methods by which it has been accomplished.

In electrical engineering to-day a polyphase alternating-current system is considered the only rational system to install for general power distribution. Ten years ago, however, at the beginnings of the Niagara power enterprise, the application of energy to industrial

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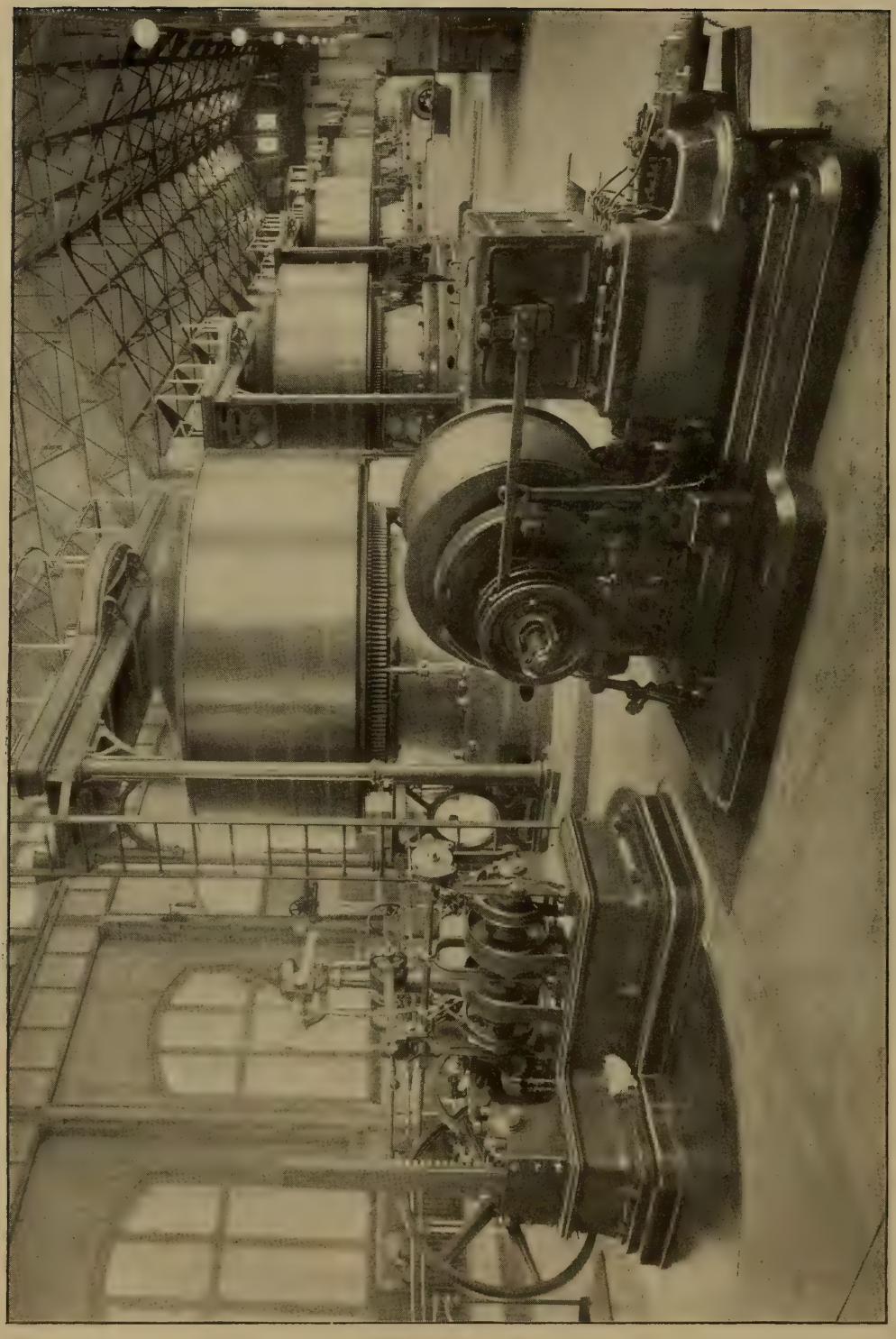
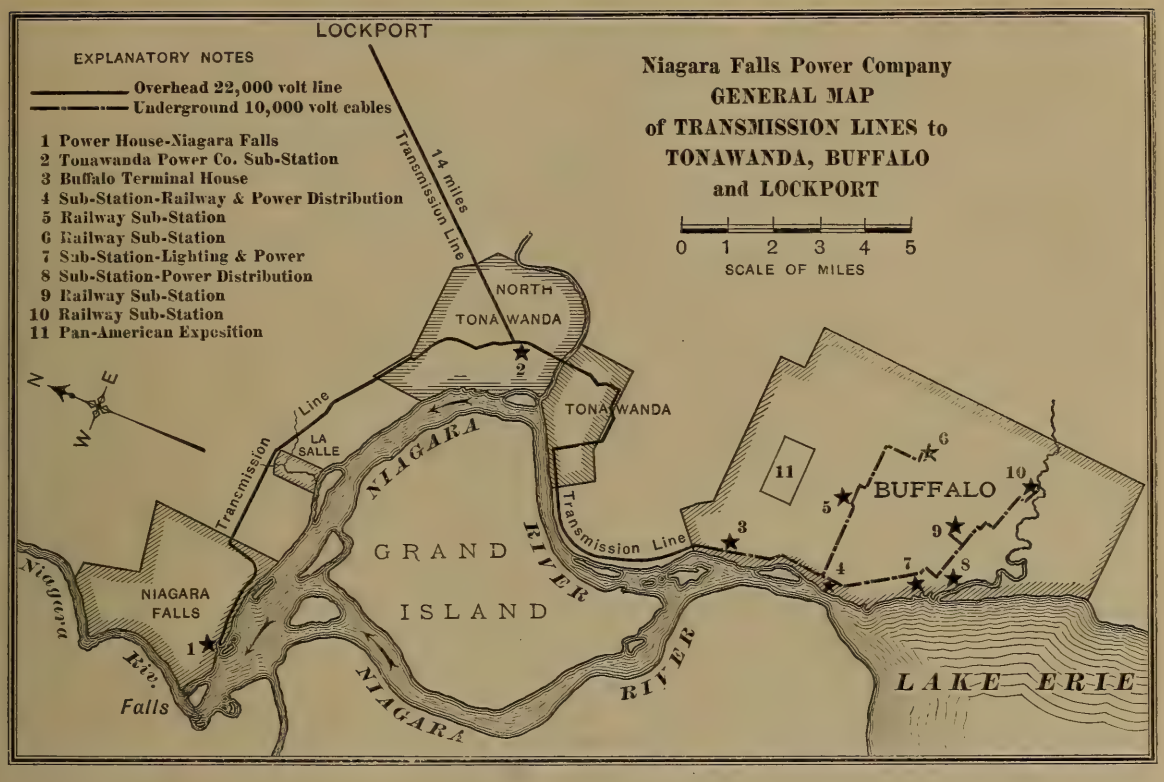


THE LATEST VIEW OF THE POWER HOUSE INTERIOR OF THE NIAGARA FALLS POWER COMPANY. TOTAL CAPACITY, 50,000 HORSE-POWER



uses was on a basis quite different from that of to-day, and the only factories which could be considered available as customers for such a power development were those who required on their premises mechanical, and not electrical, power. Consequently, schemes suggested then, which now seem somewhat fantastic, for transmitting power from the Falls by compressed air and various other means, deserved, at that time, more serious consideration. The arts of electric lighting, electric traction, and, above all, electro-chemistry, were only just beginning, and had not assumed the vast proportions of the present time, so that transmission of Niagara power by electrical methods did not have the arguments in its favour that it has now. To-day the large majority of the users of Niagara power are those who require on their premises not mechanical power, but electrical current for lighting, smelting, electrolysis, or traction.

Considering this, it is remarkable that, at that time, in spite of the undeveloped state of electrical engineering and the prejudice existing against the alternating current, the engineers connected with the Niagara enterprise should have had foresight enough to select for the power plant the polyphase system, which stands to-day as modern and meets every requirement of the latest developments in the application of energy to industry. Every user of Niagara power requires his current delivered in some special form, and it is here that the flexibility of the low frequency, polyphase, alternating-current system demonstrates its value.

The present capacity of the power house is 50,000 H. P., divided into ten electrical generating units of 5000 H. P. each. The electrical energy starts from the bus-bars of the power house at a pressure of 2200 volts, two-phase, 25-cycles, constituting, so to speak, the raw material upon which the various transformations are subsequently made. From the bus-bars the system divides into three distinct classes of service.

The first of these comprises the local distribution to factories which are in the immediate neighbourhood of the power house, these customers being supplied by underground cables directly from the bus-bars at the generator voltage, phase and frequency.

The second class might be termed the intermediate-distance transmission.

In this case the 2200-volt, two-phase current, immediately after leaving the power house bus-bars, is transformed to 11,000 volts, three-phase current by means of step-up transformers, and transmitted underground to a step-down transformer station about two miles from the power house. There it is reconverted into 2200-volt, two-phase current, and is distributed, as in the first system, for various factory uses by means of underground cables. This system is used to supply factories whose distance from the power house renders it cheaper to buy step-up and step-down transformers and transmit at a high voltage, than to buy the copper necessary to supply them with power directly from the power house bus-bars at 2200 volts. The object in transforming into three-phase current in this system and back again into two-phase at the step-down station is to save the copper resulting from the use of the three-phase transmission, which amounts to 25 per cent., and to still maintain the service to all factories uniform at 2200-volt, two-phase current. In all the underground distribution, conduits are used with the cables drawn through ducts in the usual manner.

THE LONG-DISTANCE TRANSMISSION LINES. THREE CIRCUITS WITH A CAPACITY OF 10,000 H. P. EACH AT 22,000 VOLTS

In the third class we have long-distance transmission. Here the 2200-volt, two-phase current is transformed in the power house to three-phase current at 22,000 volts and distributed on overhead bare conductors to points at a considerable distance from Niagara Falls, such as Buffalo, Tonawanda, and Lockport. The three-phase system is also used in this case on account of the saving in copper.

Since the publication of the Niagara Power Number of CASSIER'S MAGAZINE, in 1895, in which the work at Niagara was very elaborately described and illustrated, a marvellous development in the system has taken place, and an industrial community of considerable importance has sprung up around the power house. An idea of the extent of the system may be obtained from the following list of electrical apparatus which is at present installed in connection with the system and operated by it:—

Generators	50,000 H. P.
Transformers	157,000 H. P.
Rotary Converters	22,700 H. P.
Large Motors	10,300 H. P.
Total	240,000 H. P.

This list includes no piece of apparatus under 100 H. P. in capacity, such as small lighting transformers, railway motors, etc., which might fairly be considered as part of the system. The total figure seems large compared to the capacity of the generators, but that is due to the fact that step-up and step-

STEP-UP TRANSFORMERS AT THE NIAGARA FALLS TRANSFORMER HOUSE FOR THE INTERMEDIATE-DISTANCE TRANSMISSION SYSTEM. 15,000 H. P.

down transformers are connected to many of the circuits, and, in some cases, the lowering of voltage is made by two stages. The present status of the distribution of power is indicated by the following table, the figures representing the maximum loads:—

HYDRAULIC POWER.	
International Paper Co	8,000 H. P.
Niagara Falls Water Works	300 H. P.
ELECTRIC POWER.—LOCAL SERVICE.	
Niagara Falls Water Works	60 H. P.
Niagara Falls Electric Light Co	800 H. P.
Electric R.R. Sub-stations	1,000 H. P.
Francis Hook & Eye & Fastener Co	50 H. P.
Niagara Surface Coating Co	20 H. P.
Natural Food Co. (building)	2,500 H. P.
Electrical Lead Reduction Co	500 H. P.
French-Hickman Flax Fibre Co.(bldg)	600 H. P.
Acheson International Graphite Co	1,000 H. P.
Pittsburgh Reduction Co	5,000 H. P.
Carborundum Co	2,000 H. P.
Acetyvone Manufacturing Co	75 H. P.
Mathieson Alkali Works	2,400 H. P.
Niagara Electro-Chemical Co	500 H. P.
Ampère Electro-Chemical Co	300 H P.
Niagara Development Co	100 H. P.
Total	16,900 H. P.
INTERMEDIATE-DISTANCE TRANSMISSION.	
Union Carbide Co	10,000 H. P.
Oldbury Electro-Chemical Co	1,000 H. P.
Roberts Chemical Co	500 H. P.
Total	11,500 H. P.
LONG-DISTANCE TRANSMISSION.	
Tonawanda Power Co	1,000 H. P.
Buffalo and Lockport R. R. Co	550 H. P.
Lockport Electric Light Co	300 H. P
Cataract Power and Conduit Co. (Buffalo)	12,000 H. P.
Pan-American Exposition	5,000 H. P.
Total	18,850 H. P.
Total hydraulic power	8,300 H. P.
Total electric power	47,250 H. P.

The above represents the load which would result if the maximum loads of the various customers all came at the same time. They do not, however, coincide, so that the resulting maximum load is within the present capacity of the power house with one reserve machine.

In addition to the above, the Mathieson Alkali Works have contracted for 500 H. P. additional and their new plant is being constructed. The Norton Emery Wheel Company, of Worcester, Mass., have contracted for a plant of 500 H. P. The MacPherson Switch and Frog Company is building a plant for the manufacture of railway supplies which will utilise about 200 H. P., and other contracts are pending.

Perhaps no more striking illustration can be given of the universal applicability of electric power to industrial purposes than a brief description of these

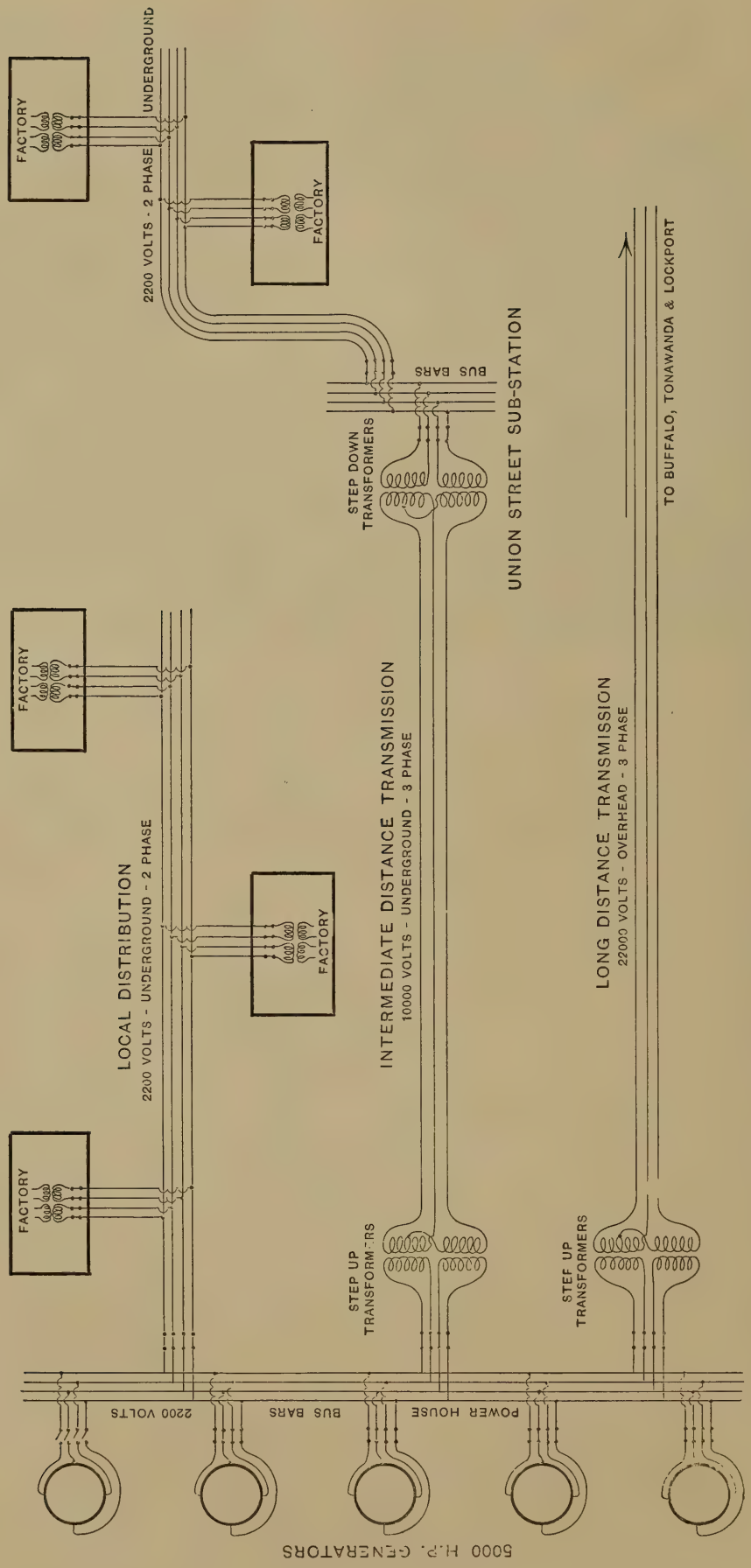


DIAGRAM ILLUSTRATING THE GENERAL SCHEME OF POWER DISTRIBUTION OF THE NIAGARA FALLS POWER COMPANY

various plants and the methods which they have adopted for applying the power to their particular needs.

The plant of the International Paper Company, with one exception, is the only one on the system which uses hydraulic power direct, without the intervention of electrical generators. It takes water from the Niagara River at the mouth of the power canal, and has its own wheel pit and turbines. The water is discharged into the tunnel of the Niagara Falls Power Company just below the power house. The power, which amounts to about 8000 H. P., is used principally for crushing wood fibre into pulp. Newspaper and wrapping paper are the chief products of the plnnt.

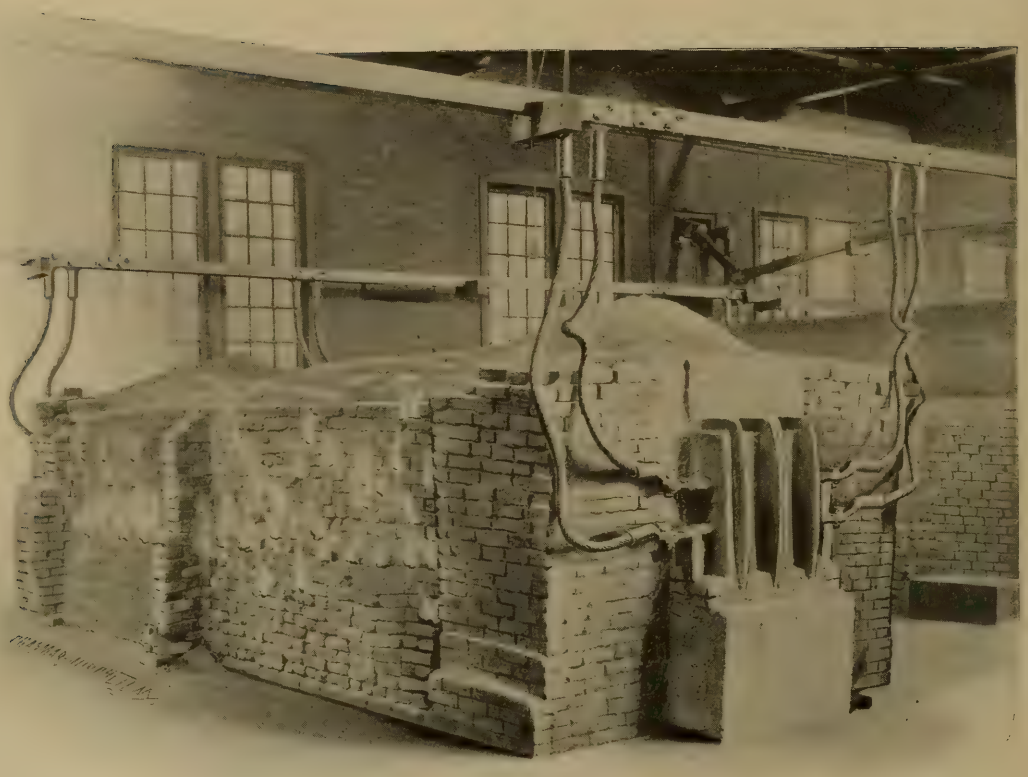
Hydraulic power is now used also in connection with the Niagara Falls Water-Works to the extent of about 300 H. P. Riedler pumps are installed at the bottom of the power house wheel pit and are driven by Pelton water-wheels. Electrical power, too, is used in connection with a 60 H. P. induction motor driving centrifugal pumps in the filter plant.

About 800 H. P. is supplied to the local lighting company, known as the Niagara Falls Electric Light Company, for driving two 400-H. P. induction motors which are belted to arc machines and high-frequency alternators for lighting the city of Niagara Falls.

The electric railroad sub-station is composed of three two-phase, 25-cycle, 500-H. P. rotary converters taking power through step-down transformers and delivering direct current at 550 volts for the operation of all electric cars within the vicinity of Niagara Falls, and operating the Buffalo & Niagara Falls Railroad to the city line of North Tonawanda.

A STEP-DOWN TRANSFORMER STATION AT NIAGARA FALLS, 15 000 H. P.

The objects of the Francis Hook and Eye and Fastener Company are indicated by its name. About 50 H. P. is used in motors for driving the various special machines. The Natural Food Company is better known by the name of the Shredded Wheat Company, which, until recently, was established at Worcester, Mass. Its new plant at Niagara Falls is nearly completed, and will be one of the best equipped manufacturing plants in the world. The works will be devoted to the manufacture of shredded wheat biscuits and



A CARBORUNDUM FURNACE IN OPERATION AT THE WORKS OF THE CARBORUNDUM COMPANY AT NIAGARA FALLS

allied products, using about 2500 H. P. for the operation of nearly 100 small induction motors driving the various special machines, and for baking by electric heat. The cleanliness of electric cooking is especially advantageous in a plant of this nature. The power will be supplied by a 2200-volt, two-phase, 25-cycle current by means of an underground conduit.

In the plant of the Electrical Lead Reduction Company about 500 H. P. is used in induction motors which drive direct-current generators. This current, at a pressure of 100 volts, is used for the electrolytic reduction of lead from sulphide of lead to the form of a sponge. This sponge may be compressed into forms required for storage battery plates or converted into litharge, red lead, lead peroxide, or white lead. At present the product is principally litharge for use in rubber manufacture.

The French-Hickman Flax Fibre Company, whose factory at Niagara Falls is nearly completed, will use about 600 H. P. in induction motors for the various mechanical purposes in the manufacture of high-grade papers from flax fibre by a special process. The International Acheson Graphite Company is engaged in the conversion of carbon in the form of anthracite coal into graphite, the conversion taking place at the high temperatures obtainable in the electric furnace. The volatile matter in the coal is driven off when the furnace reaches a high temperature, and the carbon remaining is converted into graphite. This process, whatever its exact physical nature may be, is probably similar to that which has formed the natural graphite deposits in the earth, the conversion having taken place at the high temperature existing at the time of the earth's formation. The electrical energy in this plant is utilised entirely in the form of heat at about 80 volts, single-phase.

The Pittsburg Reduction Company was one of the pioneers at Niagara Falls, being the first to receive current from the power house. The two-phase, 2200-volt supply current is lowered through step-down transformers in the plant to

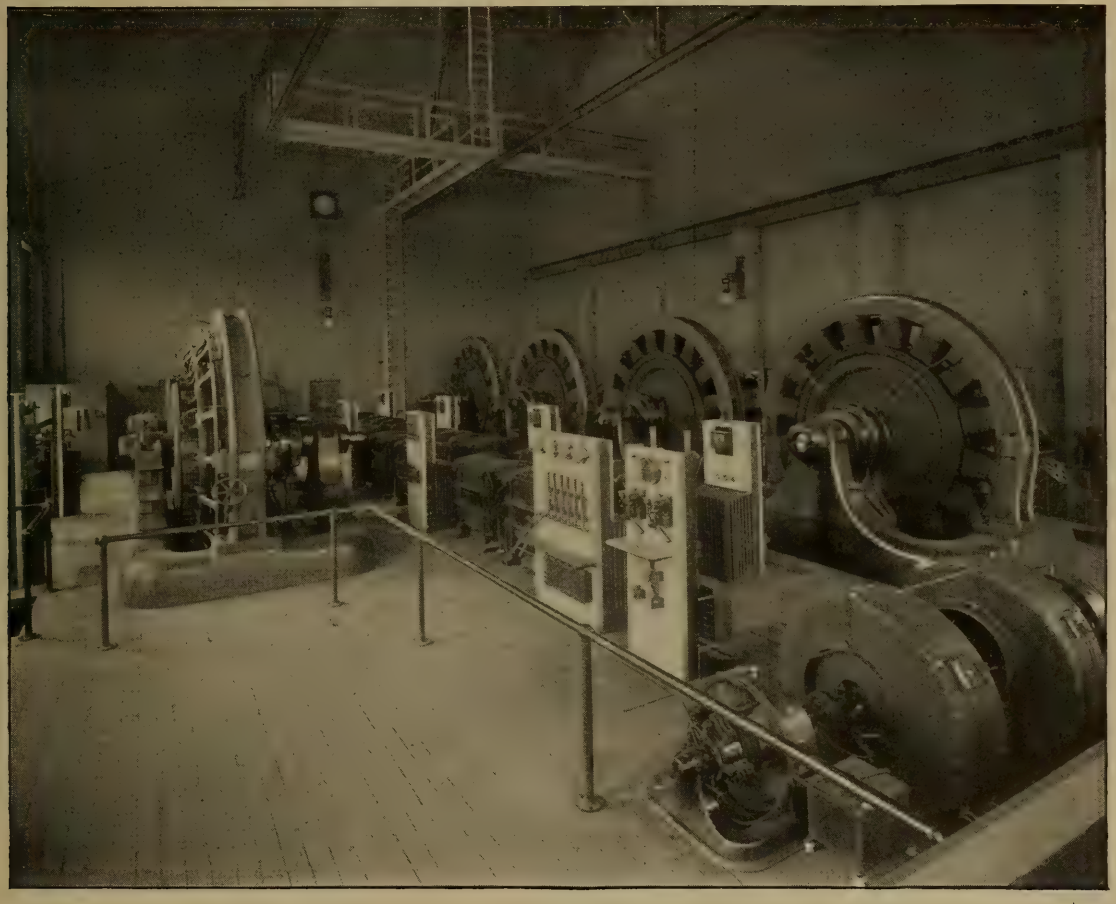
130 volts, and is then converted by six 600-KW rotary converters into direct current at 160 volts. In this form the power is used for the electrolytic separation of metallic aluminium from bauxite by the Hall process.

The Carborundum Company also is one of the earliest power users on the Niagara system, turning out the product carbide of silicon, which results from the direct union of carbon and silicon at high electric furnace temperatures. This product, although comparatively young to chemistry, has become famous as an abrasive, and its success has been a great factor in stimulating work in the electro-chemical field. In this process electrical energy is used as a producer of high temperatures in electric furnaces, single-phase, 25-cycle, 110-volt current being used.

Anyone who has seen acetylene gas burning under suitable conditions knows what an attractive means of illumination it is. The Acetyvone Company takes calcium carbide, already manufactured by Niagara power, and prepares it in such a way that it can be used in a lamp in the form of a cartridge, generating automatically the acetylene gas which is fed to the burner of the lamp. Power is used in this plant to drive motors for various mechanical uses in the factory.

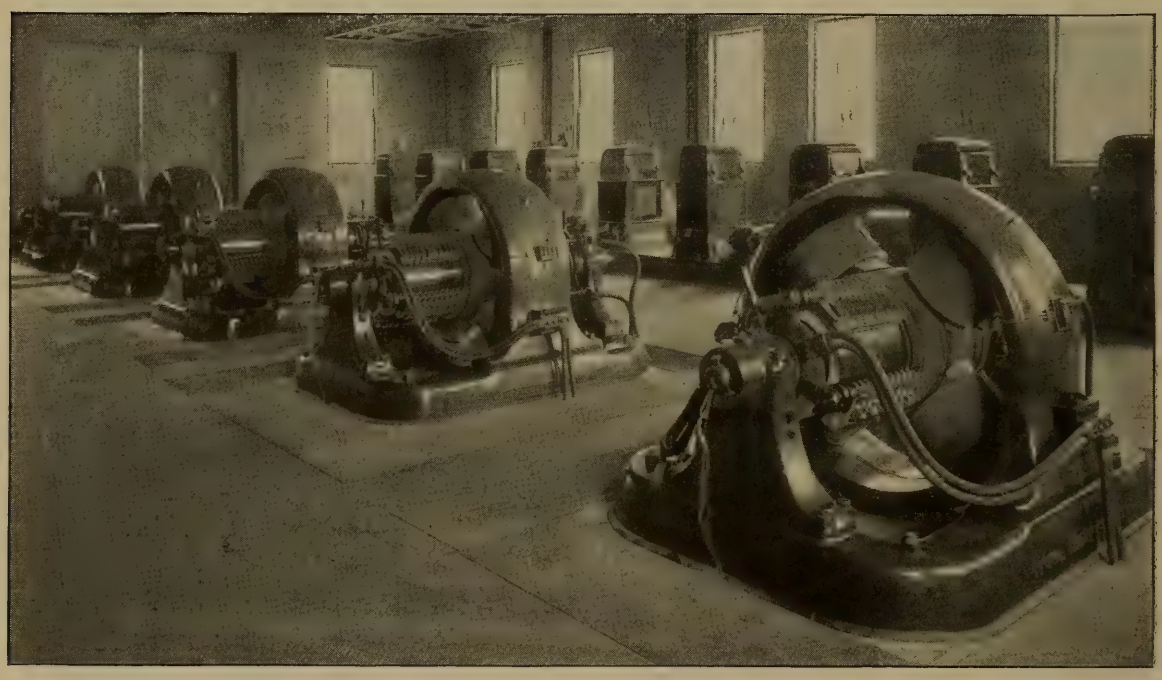
In the Mathieson Alkali Works direct current is necessary, since the process is electrolytic. Eleven 200-H. P. rotary converters change the two-phase, 25-cycle current to direct current at 230 volts, which is fed to electrolytic cells for the production of chloride of lime and caustic soda by the Castner process. Power is also used to some extent in motors for mechanical uses about the works.

In the plant of the Niagara Electro-Chemical Company four 150-KW rotary converters change the supply current to direct current at 165 volts, which is used for the production of metallic



THE ROTARY CONVERTER ROOM OF THE PITTSBURGH REDUCTION CO. 5,000 H. P.

THE UNION CARBIDE COMPANY'S WORKS AT NIAGARA FALLS. THESE WORKS USE MORE ELECTRIC POWER THAN ANY ONE OTHER FACTORY IN THE WORLD, THE TOTAL AMOUNT BEING ABOUT 15,000 HORSE-POWER



ROTARY CONVERTER ROOM OF THE OLDBURY ELECTRO-CHEMICAL COMPANY

sodium and sodium peroxide from caustic soda by another Castner electrolytic process. The Ampère Electro-Chemical Company is engaged at present in the development of several important electro-chemical processes. About 300 H. P. is used for electric furnace work and small motor driving.

The little town of Echota, on the outskirts of Niagara Falls, which affords a home for many of the employees of the manufacturing district, was built by an organisation controlled by the Niagara Falls Power Company, and known as the Niagara Development Company. About 100 H. P. is used there to operate the sewage disposal works, and for street and house lighting.

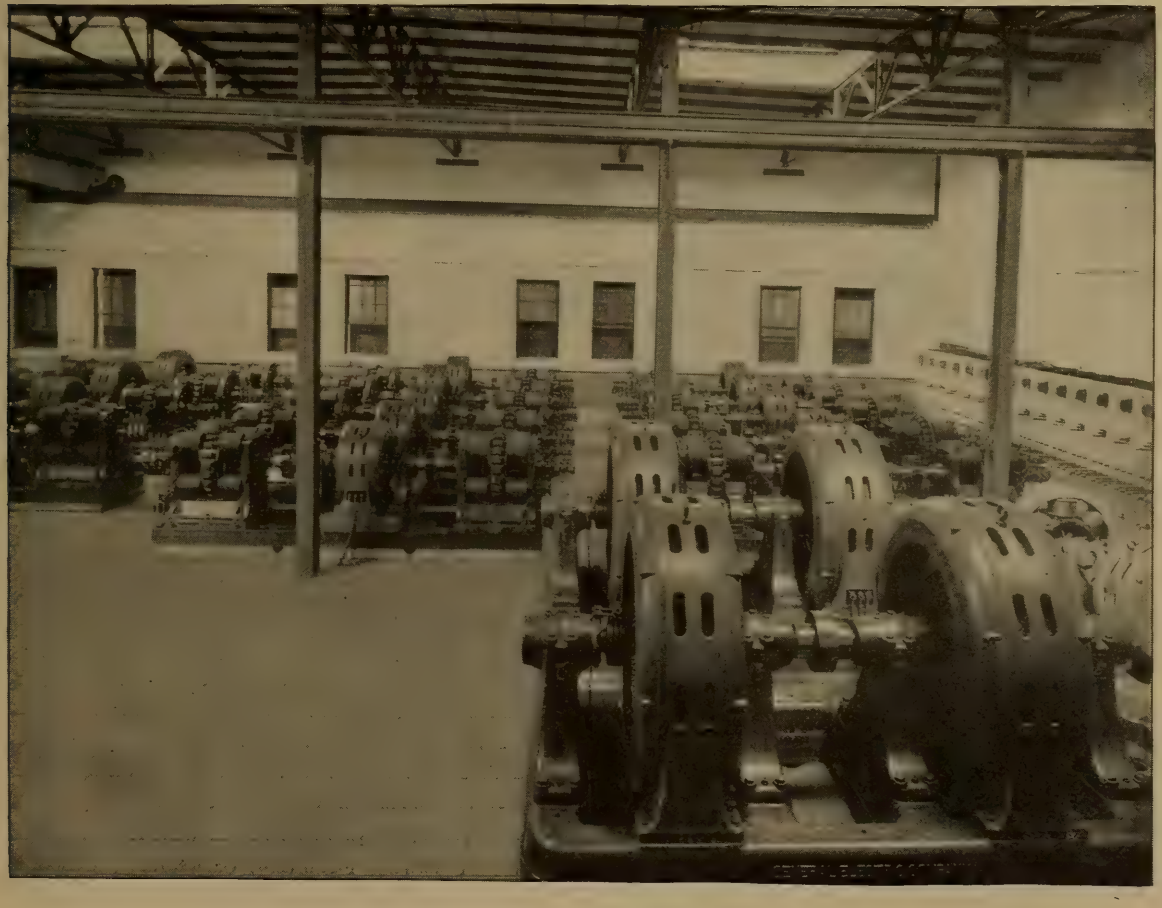
The plant of the Union Carbide Company is remarkable in many respects. It uses probably more electrical power than any one factory in the world,

and certainly more than any factory under one roof. Fifteen thousand H. P. is used at times, and 10,000 H. P. continuously. The current is distributed throughout the factory at 110 volts, and 25 cycles, the voltage of the supply circuit being lowered by eight 2000-H. P. static transformers, which are divided equally between the two phases. The current is utilised for producing high temperatures in electric furnaces for the manufacture of calcium carbide by the process which is now known the world over. Each furnace takes about 200 H. P single-phase current. The furnaces are distributed between the two phases in order to keep the system balanced.

The Roberts Chemical Company operate an electrolytic process, using direct current at a low voltage, which is converted from the supply system by means of a 500-H. P. rotary converter with step-down transformers. The product is caustic potash and other electrolytic products. In the works of the Oldbury Electro-Chemical Company the electrical power used is divided between two separate processes, one electrolytic, and the other an electric furnace process, thus utilising both alternating and direct current, and producing various chemicals.

LONG-DISTANCE TRANSMISSION.

The Oldbury Electro-Chemical Company is at present the power consumer furthest from the power house, except those users belonging to the long-distance service. There are three separate transmission circuits from the Niagara power house to Buffalo, two of which are copper, and installed on the same pole line. The third circuit is strung upon a separate pole line throughout its entire length, and is of aluminium instead of copper. This aluminium line has the same resistance as each of the other two, and is composed of three cables of 500,000 CM each, made up of thirty-seven strands. At the present market price of copper wire it is cheaper to use



THE BUFFALO GENERAL ELECTRIC CO. LIGHTING STATION. 4000 H. P.

THE TONAWANDA POWER COMPANY'S STATION AT NORTH TONAWANDA, TEN MILES FROM NIAGARA FALLS

aluminium for overhead lines where the conductors do not have to be insulated. The conductivity of aluminium is less than copper, and the price per pound is greater, but the volume per pound of aluminium is much greater than that of copper on account of the lower specific gravity of the metal. When, therefore, resistance per pound is taken as the basis for comparison, aluminium is found to be cheaper. Furthermore, on account of the increased section of the aluminium conductor and its greater lightness, it is better able to resist span strains due to gravity than a copper conductor of the same resistance. It is interesting to note that the aluminium of which these cables are made is the product of the plant of the Pittsburgh Reduction Company, which is operated by Niagara power.

Since the long-distance service to Buffalo was started in 1896, the line has been operated at a potential of 11,000 volts; but recently the voltage has been raised to 22,000, and the capacity of the three Buffalo circuits is now 30,000 H. P., with about 10 per cent. line loss. As has been pointed out before, this transmission is three-phase at 25 cycles. No power is taken from the Buffalo transmission line until North Tonawanda is reached,—a distance of about 10 miles. The Tonawanda Power Company, which is the name of the organisation distributing power in this district, is a sub-company of the Niagara Falls Power Company, and at present utilises about 1000 H. P. Part of this is distributed at 550 volts, direct current, by means of step-down transformers and rotary converters, for operating trolley lines within a five-mile radius of Tonawanda. This includes sections of the Buffalo & Lockport and Buffalo & Niagara Falls electric railroads.

From the same step-down transformers which supply current to the rotary converters, separate secondary windings deliver 25-cycle, three-phase current at 4500 volts for general power distribution throughout the Tonawanda district for machine shops, factories, and other uses. From these same transformers also are operated motors in the station, some of which drive 60-cycle generators for incandescent lighting service, and others arc machines for street lighting. It will

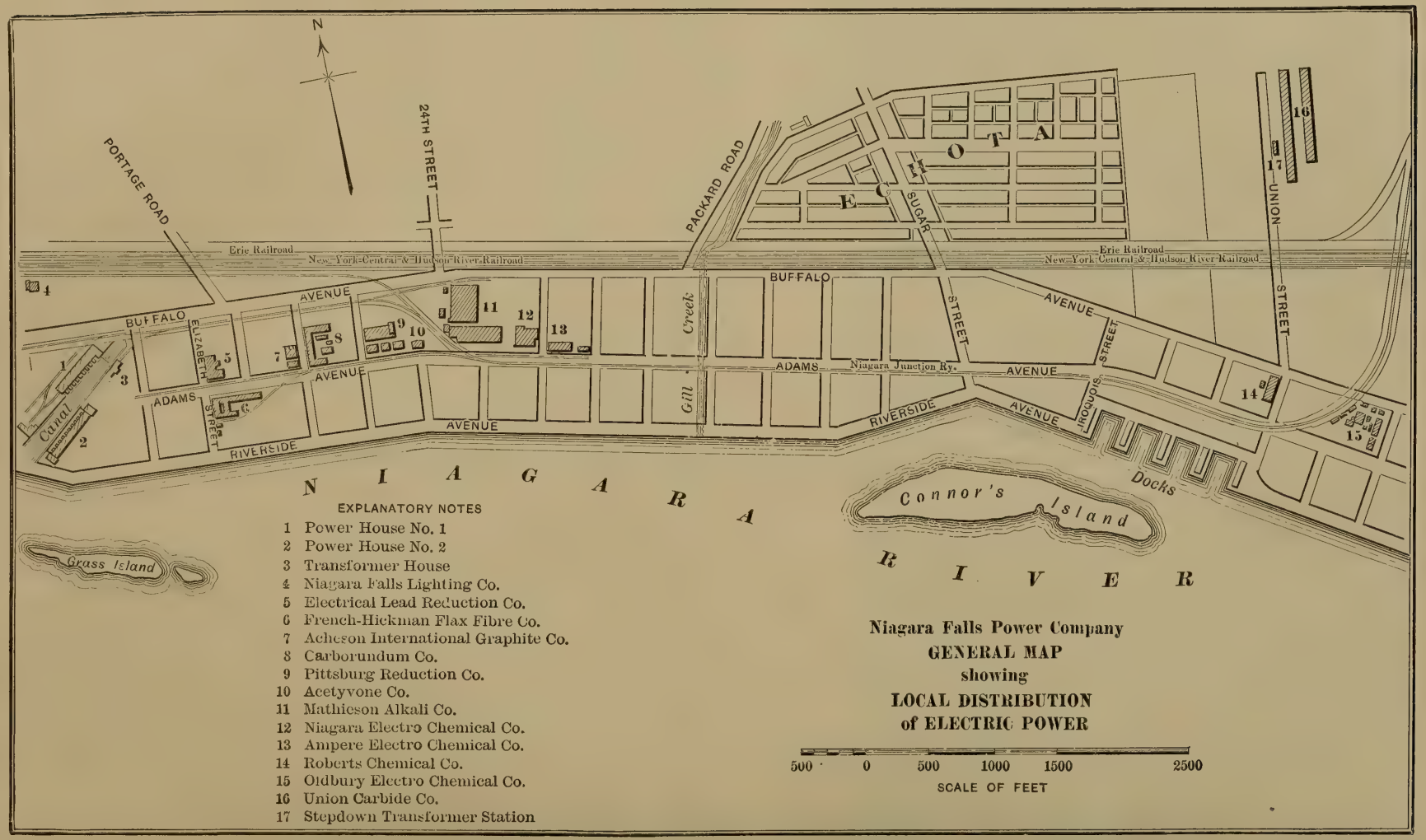
INTERIOR VIEW SHOWING STEP-DOWN TRANSFORMERS AND ROTARY CONVERTERS FOR RAILWAY SERVICE

be noted, therefore, that in this plant four separate classes of electrical service are derived from the same step-down transformers.

At the point where the Buffalo transmission line is tapped with supply lines for the Tonawanda sub-station the transmission line which supplies the city of Lockport with electric power is also connected. This branch line, consequently, has the same voltage, phase, and frequency as the Buffalo line. Its length is about fifteen miles, making the Lockport sub-stations about twenty-five miles from Niagara Falls. Three hundred horse-power is used by the local electric lighting company in motor generator sets, and about 600 H. P. in a rotary converter sub-station which supplies power for local electric railroad service. It is from this sub-station that the 40-ton electric locomotives are operated which daily haul heavy freight trains on this feeder of the Erie Railroad, hauling at times as many as twenty-eight loaded freight cars. Since this sub-station feeds direct current for a distance of ten miles beyond the sub-station, on certain sections of this route the locomotives receive their power at a distance of thirty-five miles from the Niagara power house. This is a forcible illustration of what can be accomplished by the application of electrical power to steam railroad service.

About twenty-three miles from the Niagara power house, just inside the city line of Buffalo, the overhead circuit of the Buffalo transmission line enters the terminal house of the Cataract Power and Conduit Company. This company, which also is a sub-company of the Niagara Falls Power Company, distributes Niagara power throughout the city of Buffalo, purchasing it from the Niagara Falls Power Company at the Buffalo city line, at which point the responsibility of the latter company nominally ceases. In the terminal house the 22,000-volt current is transformed by six of the largest transformers in the world, 3000 H. P. each, to three-phase, at a pressure of 10,000 volts, in which form it is distributed by underground cables to the various Buffalo sub-stations.

Ten thousand volts is the highest voltage which has been here considered


N
PORTAGE ROAD
24TH STREET
PACKARD ROAD
SUGAR
UNION
STREET
Erie Railroad
New York Central & Hudson River Railroad
BUFFALO
AVENUE
ELIZABETH
ADAMS
RIVERSIDE
Canal
Gill Creek
Niagara Junction Ry.
IROQUOIS
Connor's Island
Docks
Grass Island
NIAGARA RIVER
EXPLANATORY NOTES
1 Power House No. 1
2 Power House No. 2
3 Transformer House
4 Niagara Falls Lighting Co.
5 Electrical Lead Reduction Co.
6 French-Hickman Flax Fibre Co.
7 Acheson International Graphite Co.
8 Carborundum Co.
9 Pittsburg Reduction Co.
10 Acetyvone Co.
11 Mathieson Alkali Co.
12 Niagara Electro Chemical Co.
13 Ampere Electro Chemical Co.
14 Roberts Chemical Co.
15 Oldbury Electro Chemical Co.
16 Union Carbide Co.
17 Stepdown Transformer Station
Niagara Falls Power Company
GENERAL MAP
showing
LOCAL DISTRIBUTION
of ELECTRIC POWER
500 0 500 1000 1500 2500
SCALE OF FEET

safe for underground distribution, and it is for this reason that the 2 to 1 transformation of voltage is made necessary. The power is distributed by means of five three-conductor, lead-covered cables, each cable having a capacity of about 4000 H. P. These cables are drawn through ducts laid in concrete under the city streets. The distance from the terminal house to the Buffalo sub-station furthest removed is about eight miles, so that the long-distance transmission is by no means ended when the city line of Buffalo is reached.

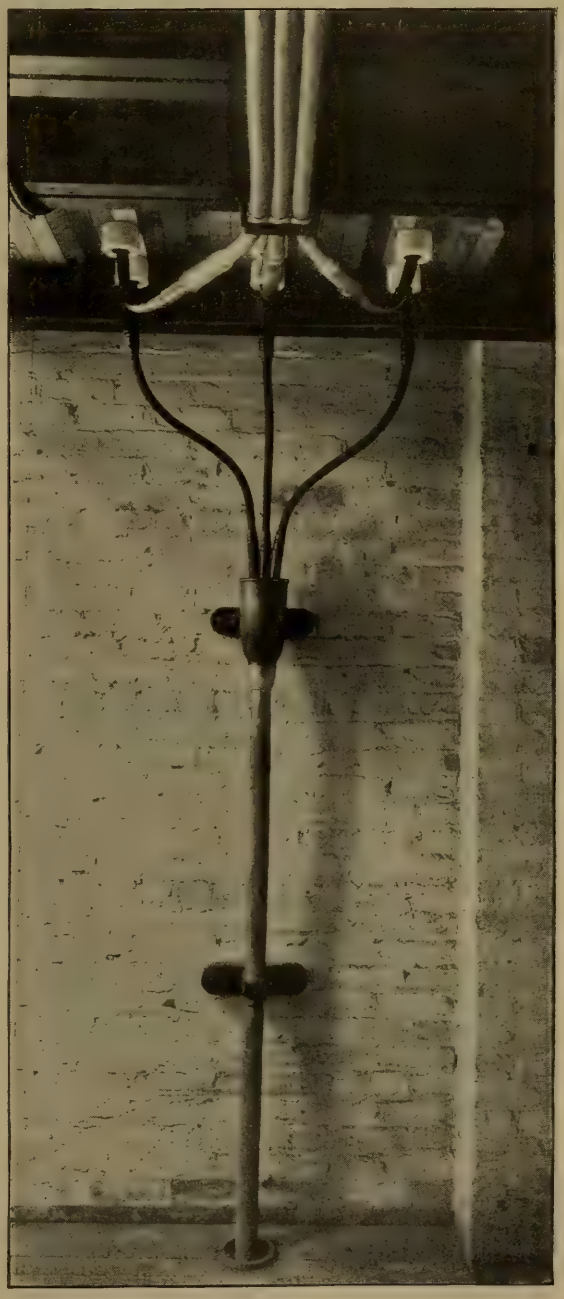
The distribution of Niagara power in Buffalo is approximately as follows:—

Buffalo Railway Co	6,000 H. P.
Buffalo General Electric Co	3,500 H. P.
Miscellaneous Power	2,500 H. P.
Pan-American Exposition	5,000 H. P.
Total	17,000 H. P.

The power used by the Pan-American Exposition is transmitted by an overhead line at 10,000 volts from the terminal house to the Exposition Grounds,—a distance of about two miles. There it is used for the many purposes to which electrical power can be applied at an exposition, notably the electric fountains and the special illuminations of the electrical tower which is to be one of the features of the Exposition.

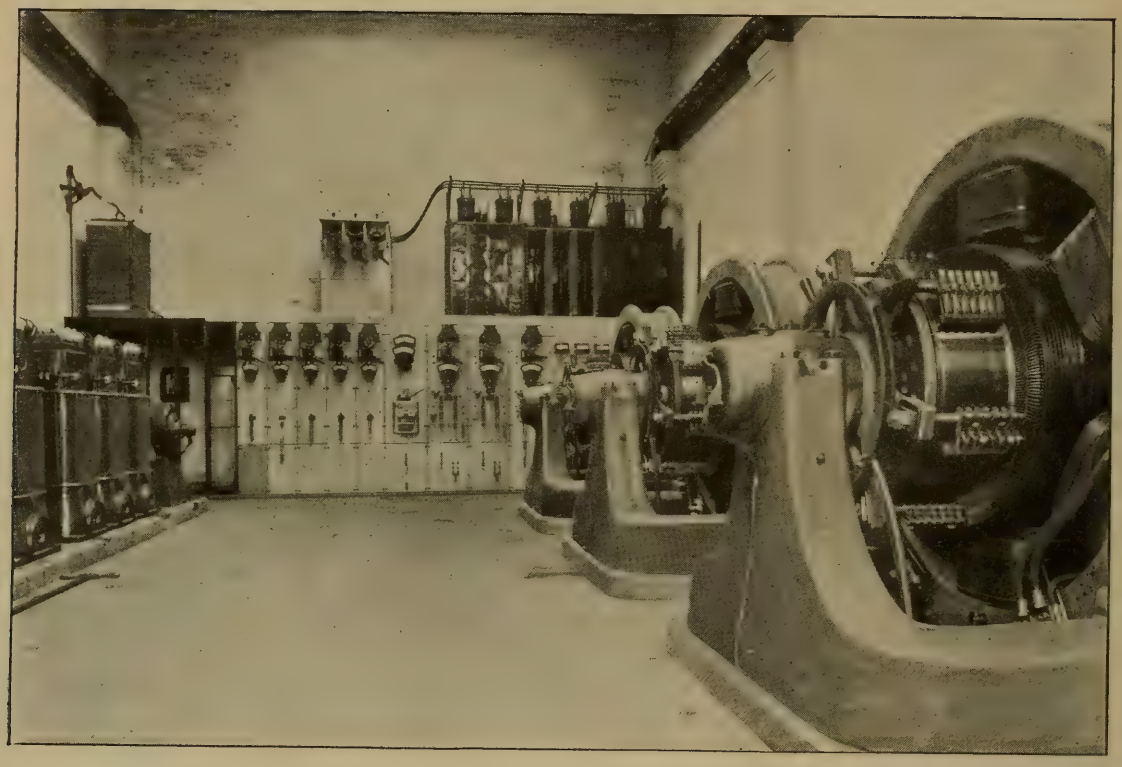
The Buffalo Street Railway Company distributes power to their trolley system from five sub-stations placed at points in the city which are centres of railway load. The 10,000-volt current from the underground cable system is lowered to 370 volts by means of step-down transformers and converted into direct current at 550 volts by means of three-phase rotary converters. There are five railway sub-stations, comprising fifteen 500-H. P. rotary converters.

The Buffalo General Electric Company supplies all the city arc lighting in Buffalo and all the incandescent lighting outside of private plants. It operates arc machines, direct-current generators for Edison three-wire distribution, and 60-cycle generators for alternating incandescent lighting by means of three-phase synchronous motors. These motors take their power at 352 volts from one of the step-down transformer sub-stations of the Cataract Power and Conduit Company. The use of motor-generator sets in this station makes the lighting circuits independent of the voltage fluctuations on the long-distance transmission line.

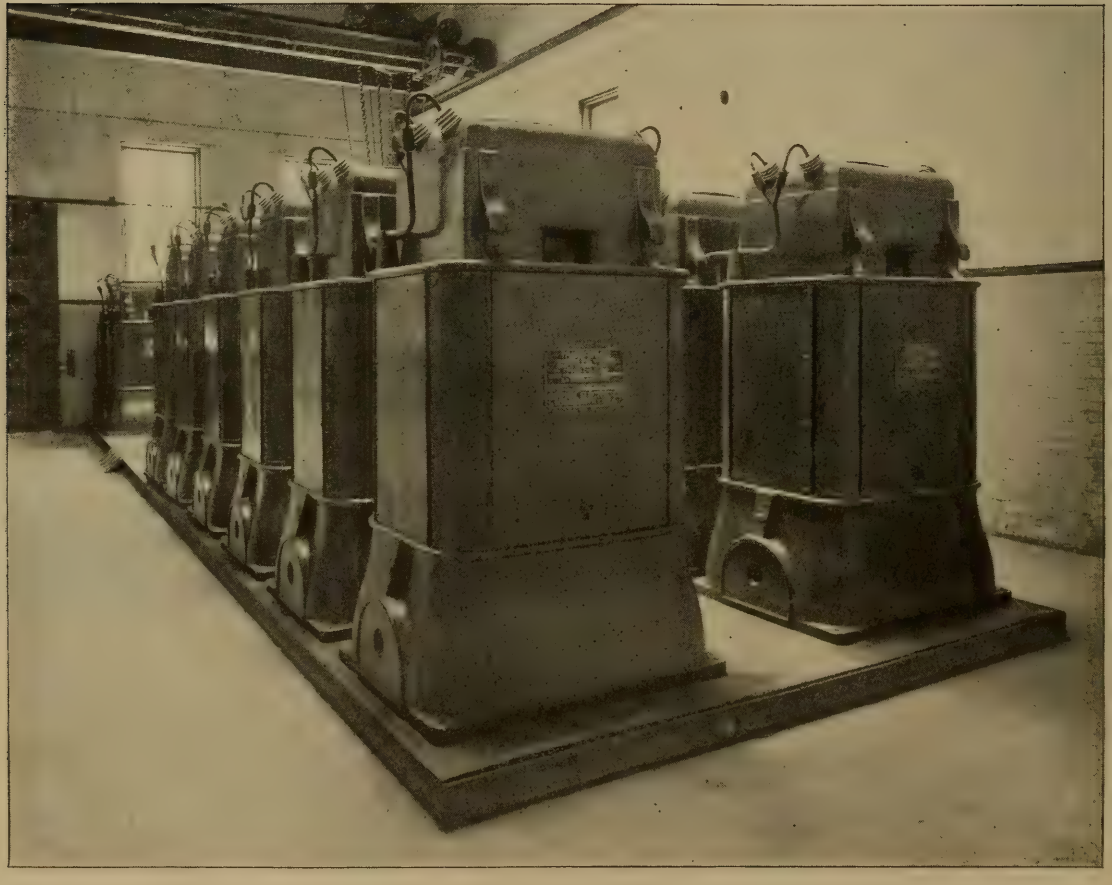


A TERMINAL OF THE BUFFALO UNDERGROUND CABLE, TRANSMITTING 4,000 H. P. AT 10,000 VOLTS

In addition to the railway sub-stations, and the sub-station of the Buffalo General Electric Company, the Cataract Power and Conduit Company operates three sub-stations throughout the city, the purpose of which is to lower the



ONE OF THE BUFFALO STREET RAILWAY SUB-STATIONS



ONE OF THE SUB-STATIONS AT BUFFALO OF THE CATARACT POWER & CONDUIT COMPANY. 4000 H. P

voltage of the underground system from 10,000 to 2200 volts, three-phase At this potential the power is redistributed to the various users to whose premises it would not be convenient to deliver current at as high a voltage as that of the underground mains. The equipment of these sub-stations consists merely of step-down transformers and distributing switchboard panels. The power delivered at 2200 volts, three-phase, is used largely by grain elevators, in which the convenience of applying power by electrical methods is especially desirable. There is also a large number of machine shops and factories of various kinds which are operated from these circuits.

Probably no long distance transmission line in the world has dependent upon it such important commercial interests as that which carries Niagara power to the city of Buffalo, and no line in the world is a better illustration of the practicability of transmitting large amounts of power by electrical means over long-distance lines. Every trolley car in Buffalo receives its power supply over this line, and every arc lamp, as well, in the streets of Buffalo, and many of the important factories of that city have no other source of power for their operation than electric power from Niagara Falls.

Such has been the fulfilment of the prophecy made not many years ago that, to transmit Niagara power for a distance of more than two or three miles from the Falls, would be "commercially impractical!" Already it has reached out, in the case of some of the arc lamps, on the outskirts of Buffalo, to a distance of nearly forty miles, and the limit has not yet been approached.

On account of the great importance of the Buffalo transmission line, it had to be constructed with the utmost care in order to avoid interruptions in service from mechanical defects, and had to be insulated in such a way as to be absolutely unaffected by any of the stresses of weather to which it might be subjected. All trees within possible danger distance of the line were removed.

From the various applications of power which have been outlined it will, perhaps, be noted how comparatively few of the power customers utilise the electrical power in the exact form in which it leaves the terminals of the generators, and what a large variety of secondary systems are derived by transformation and conversion. The following are some of the systems derived from the primary supply mains at 2200 volts, two-phase, 25 cycles:—

25 CYCLES.

2,200 volts	3-phase.
22,000 volts	3-phase.
11,000 volts	3-phase.
4,500 volts	3-phase.
330 volts	3-phase.
350 volts	2-phase.
110 volts	single-phase.
30 volts	single-phase.

60 CYCLES.

2,200 volts	2-phase.
8,000 volts	single-phase (arc).
110 volts	2-phase.

125 CYCLES.

2,200 volts	single-phase.
8,000 volts	single-phase (arc).

DIRECT CURRENT.

100 volts.	130 volts.
160 volts.	250 volts.
550 volts.	8,000 volts (arc).

All these systems are derived by simple transformations by means of static transformers, rotary converters, or motor-generator sets. On a large system of power distribution, such as that at Niagara, there are necessarily many power users with widely differing requirements, and the list which is given illustrates how well this demand is met by the flexibility of the polyphase alternating-current system.

Such, then, is the present status of power distribution from the power house of the Niagara Falls Power Company, and a glance at its past development indicates the lines along which it is likely to grow in the future. As the manufacturing arts advance, the element of power becomes more and more important and cheap power therefore more demanded. Electro-chemistry is a new art, and one which has great possibilities ahead of it. The high temperatures obtainable in electric furnaces have opened up a new field to chemical synthesis, and it is likely that many as yet undiscovered processes, which will require large amounts of electrical power for their operation, will be

AN ELECTRIC LOCOMOTIVE ON THE BUFFALO & LOCKPORT RAILWAY. OPERATED BY NIAGARA POWER, 25 MILES FROM THE POWER HOUSE

brought to light. The supply of power for electro-chemical purposes is especially desirable in a water power plant where large investment is necessary, for the power used by these processes is practically constant for twenty-four hours of the day, thus tending to reduce load "peaks" on the total station output.

The economical distance to which power can be transmitted extends every year as the general demand for power increases and methods of handling high voltages improve, and the electric equipment of steam railway systems, which is certain to come in time, will open up a further field for the long-distance transmission of large amounts of power from a central point.

A second Niagara power house is at present in the course of construction by the Niagara Falls Power Company. This is located near the present one, on the opposite side of the inlet canal, and will be essentially a duplicate of it. It is expected that this will start into operation by the end of the present year. This new power house, when complete, will contain eleven 5000 H. P. generators, which, together with the present plant, will make a total capacity of 105,000 electrical horse power.

When it is considered what a great amount of important manufacturing is at present being done with Niagara power, both in Buffalo and Niagara Falls, that all the electric street railways in Niagara Falls and Buffalo and intervening country are operated by this power, and that all the electric lights for a distance of forty miles in this populous section are operated by it, it will be seen that Niagara no longer devotes all its energies to the production of spray and bubbles. And yet so immense is the total power of Niagara Falls that the part diverted in the cause of industry is negligible by comparison.

SPEED REGULATION OF WATER POWER PLANTS

THE PRACTICAL SIDE OF THE PROBLEM

By Allan V. Garratt

THE art of governing water power plants is still in a formative stage. The theory of the subject is better understood than the practice. The former must necessarily take a mathematical form and is of interest chiefly to those engaged in designing water-wheel governors. The latter is of interest to those who are engaged in the work of designing and building water power plants. This article will deal entirely with the practical side of the question, and will be illustrated by referring to details of plants which have been found satisfactory.

It may be very appropriate to ask first, why is it so difficult to govern the speed of a water-wheel? Why, for example, is it more difficult to hold the speed of a water-wheel constant under variable load than it is to do the same thing with a steam-engine? In one respect the conditions of the two things are alike, for we know that when the steam-engine or the water-wheel is running at a uniform speed there is an exact balance between the foot-pounds of energy being developed in unit time by the steam in passing through the cylinder, or the water in passing through the water-wheel, and the work being done by the engine or water-wheel. The energy and the work are equal and opposite forces, and, consequently, the rate of motion remains the same; or, as a helper around the plant would probably say, the power and load are constant, and, of course, the speed does not change.

Now let us suppose we increase the load suddenly. Take, first, the case of a steam engine. Let us suppose that the load consists of the friction between a brake and the face of a pulley, and we suddenly hang a heavier weight on the brake. If nothing is done to prevent it, the speed of the engine will fall to such a point that the increased friction and the slower speed will be just equal to the less amount of friction and the higher speed, and the engine will again run at a uniform, though slower speed. But the speed will not instantly fall to the lower uniform speed, because all of the rotating parts of the engine and pulley have in them energy of motion which must be expended on the brake before the speed will fall to a uniform slower motion. This will take an interval of time which may be readily calculated.

But now we will suppose that the engine is provided with a good governor. Soon (a small fraction of a second) after the heavier weight is hung on the brake the governor feels the slightly decreasing speed, and at once sets the valve gear to a position which admits enough more steam to the engine to take care of the increased load, and the speed almost at once comes back to the normal, having varied but very little from it. A first-class engine governor will set the valve gear to the correct position for new load in less time than it takes the engine to make one stroke, so that the next time the engine takes steam after the load has changed the amount of steam admitted will be just right for the new value of load.

The engine governor is aided in performing its work by a number of things, most prominent among which are the following:—1st. The valve gear and valves are very light, and their position may be changed with great rapidity. 2d. The steam is highly elastic, in a greatly compressed state, and is very

mobile, so that, when permitted to do so, it enters the engine cylinder with great velocity, and begins to do its work in an almost inconceivably short space of time. 3d. Steam is very light, and possesses very little inertia in proportion to the dynamic energy it develops, so that its velocity in the pipes and passages between the boiler and cylinder may be instantly changed without changing effective cylinder pressure appreciably.

These factors should be carefully remembered, for, unfortunately, they are all lacking in the water-wheel, and it is in the skillful attempt to approximate them, or, failing in that, to compensate for the lack of them, that the art of water-wheel regulation consists. In passing, it may be said that, with an engine of proper proportions, equipped with the best form of governor, it is possible to instantly throw on or off the entire load without increasing or decreasing the speed more than 1 per cent. from the normal, the variation lasting not over two seconds. This has never been accomplished with a turbine water-wheel, though it has been approached, and with an impulse or tangential water-wheel it has been nearly realised. We will now look at the obstacles to be overcome in governing water-wheels and the way they have been most successfully surmounted in practice.

Suppose that in place of the steam-engine we have a turbine water-wheel doing work by overcoming the friction between a brake and the face of a pulley. If we suddenly hang a heavier weight on the brake, the speed will drop to a new constant value, the same as in the case of the steam-engine, only in the case of the water-wheel it will probably arrive at its constant lower speed sooner than the steam-engine, for the reason that the rotative parts will probably be lighter and smaller than those of the steam-engine, and hence contain less energy of motion or kinetic energy.

But now we will suppose that the water-wheel is supplied with a governor. What will happen? Soon (a small fraction of a second) after the heavier weight is applied to the brake the governor will feel the slightly decreasing speed and will begin to open the water-wheel gate, or gates, so as to admit more water. But these gates, instead of being light and highly lubricated, like the engine valve, are ponderous affairs, weighing, possibly, thousands of pounds; they are, perhaps, immersed in gritty water and grind in their seats, and the rigging used to move them is very massive, so as to be able to stand the strain. The water-wheel governor evidently has more of a problem to contend with than had the engine governor. Something must be done, for the speed is falling rapidly. The governor takes hold of the gates, and, with a mighty effort (perhaps 15 or 20 horse power for a second or two), moves them rapidly to the correct position for the increased load. But the trouble is not yet at an end. The more widely opened gates demand more water; it must approach the water-wheel faster, but, unlike the steam, which shot through the pipes and ports with lightning speed to do its work, the water increases its flow deliberately, forced onward by the influence of gravity alone.

If the water-wheel is set in an open flume of ample dimensions the water will gain the proper velocity into the wheel approximately in accordance with the well-known laws for spouting velocity. If, however, the water-wheel is in a closed iron case at the end of a long and more or less horizontal feed pipe, the action will be much slower, for it is evident that if, for example, the amount of water entering the wheel is to be doubled, the velocity of the water in the feed pipe must be doubled, and if the feed pipe is more or less horizontal, the force of gravity does not act on the enclosed water to good advantage, and hence it will gain its new working velocity very slowly.*

In any event, the governor will move the gates to the correct position for new

* A mathematical treatment of this subject by the author is given in Vol. XVI. Transactions of American Institute of Electrical Engineers, page 361.

load before the water gets up sufficient velocity to do the increased work, and the tendency will be for the governor to keep on opening the gates until the output of work on the part of the water-wheel equals the load upon it. The position in which the gates would be left would be by far too wide open for the final water velocity, and the speed would, consequently, run much too high. The governor would then try to rectify the difficulty by partly closing the gates; but then a new difficulty would develop,—as will be described more in detail later on,—and the gates would be closed too far. The practical result would be that the governor would move the gates rapidly, first open and then shut, in a futile attempt to stop them at the right place, until finally a balance of forces would be arrived at and the governor and gates would come to a rest. The writer has seen a water-wheel governor make forty-seven unsuccessful attempts to stop the gates at the right place before it finally hit it just right.

Now let us suppose that the speed of the water-wheel has finally become constant under the increased load, and we then suddenly lift off a part of the weight on the brake. The governor will soon (in a small fraction of a second) feel the slightly increasing speed, and will begin to close the water-wheel gates. It will now experience another difficulty different from that found when the load was suddenly increased. The gates are closed by the governor for the purpose of decreasing the quantity of water which will pass through them in unit time. The water is approaching the water-wheel through a more or less contracted channel, perhaps through a closed pipe of considerable length. It is impossible to slow up this moving water column without doing work upon it. If the channel is open, this expenditure of energy will pile up the water over the wheel slightly,—that is, slightly increase the head; if the channel is closed, the expenditure of energy will increase the water pressure at the water-wheel more or less, which is the hydraulic equivalent of increasing the head. This pressure in the closed pipe will be directly as the length of the pipe and the velocity of the water in it, and inversely as the time in which it is slowed down to its new constant velocity. If the above quantities are expressed in feet, feet per second, and seconds, and their algebraic sum is multiplied by 0.01324, we shall have approximately the average pressure in pounds per square inch which will be developed at the water-wheel. In any event, as the governor closes the gates the water pressure on them increases, and more water will pass through into the water-wheel, making it turn faster than it should. The practical result will be that the governor will want to keep on closing the gates further than it should. But after a time the energy of motion in the water column will be expended, and then the water will be found at its old working pressure and the gates will not be open wide enough. The governor will then want to open the gates on account of the speed falling, and will shoot back and forth a number of times before it stops the gate at the correct position, and the normal speed of the water-wheel will be greatly disturbed.

With high heads and nearly vertical feed pipes the speed will be less disturbed when the load suddenly increases than when it suddenly decreases, and in either case it will be less disturbed than when the head is low and the feed pipe more or less long and horizontal. In the latter case the speed will be less disturbed when load is suddenly decreased than when it is suddenly increased, but in either event will be more disturbed than with high head and nearly vertical feed pipe.

Some readers who are close observers will be inclined to say that the above brief description of the behaviour of a water-wheel under variable load does not describe some of the phenomena exactly, and omits all mention of some of the things which take place. But an absolutely accurate description of even the phenomena which have been alluded to would extend this article far beyond permissible limits, and a complete treat-

ment could be attempted only in mathematical form, which would be alike tedious and unnecessary for the purpose of emphasising the important things to be considered in laying out a plant so as to obtain the best attainable speed regulation.

Enough has been said, however, to point to three things which should have consideration. First, the general design of plant. Second, the design of water-wheel gates and connections between them and the motive part of the governor. Third, the design of the water-wheel governor itself.

GENERAL DESIGN OF PLANT

Experience has shown that unquestionably the easiest plants to govern are those in which the turbines are set in open flumes leading directly from open forebays. The areas of both the flumes and forebays should be of ample proportions, so that the largest and most sudden variations of load will cause little change in level of water over the turbines. It is equally important that tail races be of ample proportions, so that the level of tail water will be maintained very nearly constant. Sudden variations in either head water or tail water level are sure to cause difficulties in obtaining speed regulation. Water flowing at a variable rate in open channels often behaves in the most astonishing and annoying fashion, baffling all attempts at calculation; and crooked or badly designed entrances and passages, either in head water or tail water, frequently set up periodic wave motions which cause no end of trouble. All wetted surfaces should have easy, graceful curves, and care taken in this particular will well repay the trouble in good results obtained.

Where the head is comparatively low, practice has shown that there is but little choice, so far as speed regulation is concerned, between wheels set vertically and those set horizontally. Heads below 15 feet usually require vertical setting. Considerations not germane to this article point to the horizontal setting of wheels in open flumes where the natural conformation of the water power permits. Many plants with horizontally set wheels in open flumes have been built in which the design is almost perfect. It would be tedious to enumerate a great number of them, but it may be useful to point to the plant of the St. Anthony Falls Water Power Company, of Minneapolis, Minn., U. S. A., and that of the Hudson River Power Transmission Company, at Mechanicsville, New York, as models of design for this class of plant from the standpoint of regulation. Many large plants are now being built which are designed on these same general lines, and in such plants it is always safe to predict that great accuracy of regulation will be obtained if the machinery is well adapted to the requirements.

Typical settings of vertical turbines may be found in such plants as that of the Lachine Rapids Hydraulic and Land Company, of Montreal, or that of the Fries Manufacturing Company, of Winston, North Carolina. Several very large plants are now being constructed on the general lines of the two last named plants, and it is perfectly safe to predict that the speed regulation will be of a high order. All four of the above named plants have been recently elaborately described and illustrated in various technical journals, and hence it seems unnecessary to burden these columns with drawings of them, as they are available to all readers.

Before leaving this portion of the subject it may be permissible to say that an examination of a great many water powers has led the writer to wonder why so many of them have been developed in such a manner as to necessitate the use of long feed pipes, with all their attendant evils, when a little more care in the preliminary design would have resulted, at no greater expense, in water-wheels set in practically open water.

The above referred-to element of design has undoubtedly been less considered than any other of equal importance. The facts that you cannot change the velocity of a column of moving water without changing the amount of kinetic energy which it contains, and that the

force of gravity acting on water works to its best advantage only vertically, should never be lost sight of. The fact that fluid pressure is the same in all directions is apt to blind one to the importance of the latter statement.

But it is not necessary that the turbines should be set in open water, though that is the best arrangement. As a general statement,—and this must be taken as a very general statement,—it may be said that if the hydraulic slope from open head water to open tail water is 30 degrees or over, very satisfactory speed regulation may usually be obtained by a careful selection of water-wheels and governors, even with the largest and most sudden load variations. No safe and general rules for a plant of this kind can be laid down. Each individual case must receive a careful examination. The dynamic and kinetic quantities must be carefully calculated and compared with examples of successful practice. The majority of water power plants belong to this class, and it is unfortunate that the art is not yet sufficiently advanced to reduce the subject to the exactness which would permit of its formularisation for general use.

A number of mathematical theories have been advanced from time to time with so much confidence as to lead a reader to suppose that they had been demonstrated. The writer has not been able to apply any of them successfully to actual practice. It is found in practical hydraulics that one carefully carried out experiment is worth more than many mathematical deductions based on pure theory. The difficulty is to get together all the factors in the equation, some of them being pretty sure to be overlooked.

A long list of plants of this class could be written, in which the most satisfactory speed regulation has been obtained under very severe load conditions. A study of the design of these plants reveals the fact that there is a wide range in the angles of hydraulic slope and in the ratio between the kinetic energy in the enclosed water column and the dynamic energy developed by the water passing through the turbines. But a comparison of carefully tabulated results would show clearly that the greater the hydraulic angle, and the smaller the kinetic energy in the enclosed water are, in proportion to its dynamic output, the more accurate the speed regulation is under similar load conditions. The plants of the Kalamazoo Valley Electric Company, at Allegan, Mich.; of the Concord Land and Water Power Company, at Sewall Falls, N. H.; the United Electric Light Company of Springfield, at Indian Orchard, Mass.; the United Gas and Electric Company, at Berwick, Me.; the Toledo and Maumee Valley Electric Company, and the Niagara Falls Hydraulic Power and Manufacturing Company may be regarded as typical of this class. Each one of these plants is sufficiently different from all the rest to be regarded as typical of a sub-class of its own, though they all come under the general class now being considered. In all of them the degree of speed regulation which has been obtained is eminently satisfactory.

But there is still another class of plants which is the most difficult of all, and the resources of the engineer are taxed to the utmost to produce satisfactory regulation in them, though such efforts are frequently crowned with success. This class of plants consists of those where the water-wheels are situated hundreds or thousands of feet from open water, and where the water is brought to the water-wheels in practically horizontal pipes. If in such plants a large portion of the head be developed in draught tubes below the water-wheels, the case becomes serious indeed. Frequently, as was referred to earlier in this paper, developments of this kind are entirely unnecessary, and an inspection of the lay of the ground would lead one to the opinion that some one who had a hand in making the design had an interest in selling the pipe line. Sometimes, however, there is no other possible development, and the water power, if developed at all, must be developed through long pipes.

In these plants the water-wheel gov-

ernor alone, no matter how perfect its design and construction, cannot produce satisfactory speed regulation. Fortunately, there are two things which can help the governor out. One is the standpipe; the other, the relief valve. Both of these must be especially designed for the particular conditions under which they are to be used. In some cases the standpipe is of the most use; in others, the relief valve. Occasionally both are required. This matter may be best illustrated by referring to a few specific cases, which will be selected as illustrating widely different, yet typical, natural conditions.

Suppose it is found necessary to bring the water either in a long, horizontal pipe, with its upper end practically at open water level, or in a contracted open channel, to the water-wheel located at a considerable distance from the dam. In this case the standpipe, in the ordinary acceptance of the term, is of no use. Starting with a small standpipe, gradually increasing its area, would show by experiment that the larger you make it, up to a certain point, the better would be the regulation. It would finally become a large open tank in which the water-wheel would be preferably set, or, if that were not feasible, the tank would be placed at the water-wheel end of the flume and connected to the wheel case by a very short pipe of ample area.

There has been sufficient practice with this sort of plant to permit of the requisite dimensions of the open tank being predetermined with accuracy. Such a plant as has been described above is that of the Driggs Seabury Gun and Ammunition Company, of Derby, Conn., U. S. A. This plant, as originally designed, was ungovernable, as was pointed out by the writer before it was built. Subsequently placing an open tank of suitable proportions directly behind the wheel case made it possible to obtain very accurate speed regulation under very sudden and large load variations.

Now suppose a case much similar to the last above named, but in which the natural conditions necessitate setting the water-wheels up nearly to open water level, a large portion of the head being developed in long draught tubes beneath the water-wheels. If these water-wheels were set in an open tank, as in the previous case, the water would be very shallow over them. If also the natural conditions or the design of building prohibited the use of a tank of sufficiently large area, it would be found that, upon the governor suddenly opening the gates to take care of a sudden load, the water would be sucked down through the draught tubes, lowering the water level over the wheels sufficiently to admit air into them. This would immediately pass into the draught tubes, breaking the water seal in them and emptying them of water, and the speed of the water-wheels would fall greatly below normal until the water in the long, closed, horizontal feed pipe accelerated sufficiently under the influence of gravity to again fill the turbines and draught tubes and drive out the air.

In this case we should have recourse to a different device. The turbines would be placed in a closed iron flume, connected directly to the end of the long feed pipe. No standpipe nor open tank would be used, but on top of the feed pipe, directly behind the water-wheel case, would be placed a very large flapper valve, so arranged that it could open outward, but not inward. Upon load, and consequently the water-wheel gate orifice, being suddenly decreased, the flapper valve would open like an old-fashioned skylight on hinges, and the water, which otherwise would increase pressure on the water-wheels, would escape. Upon load, and consequently water-wheel gate orifice, suddenly increasing, the pull of the draught tubes would shut the flapper valve down water-tight on its seat, so that no air could enter, and the entire pull of the draught tube would become effective in accelerating the water velocity in the long, horizontal feed pipe, which consequently would acquire its increased working velocity in a small fraction of the time otherwise required. Experience has taught the proper area and design of the flapper valve. A plant

such as that just described is that of the United Gas and Elctric Company, of Dover, N. H., at South Berwick, Me., in which a satisfactory speed regulation is obtained, in spite of the very unfavourable conditions encountered.

Now suppose a case in which the pipe line is very long and the head quite high. In such a case it is, of course, impossible to use the devices heretofore named, and a properly designed standpipe will here aid a good water-wheel governor in producing good speed regulation. The cross section of the standpipe is obtained by taking into consideration the length of time necessary for the force of gravity to increase the velocity of the water in the flume from its minimum to its maximum working value, and then making the cross section of the standpipe such that during that interval of time the water level in the standpipe will not fall sufficiently to lower the effective head on the water-wheels below the point which can be taken care of by the governor without lowering the rotative speed of the water-wheel below permissible limits.

The height of the standpipe should be but little greater than the hydrostatic head,—that is, when the water-wheels are at a rest and the water is not moving in the flume, the level of the water in the standpipe should be very near its top. This will, of course, result in water spilling over the top of the standpipe whenever load, and consequently gate orifice, is suddenly decreased. This spilling of water, though inconvenient, is necessary; for if the standpipe is made sufficiently high to prevent the water spilling over the top, it is evident that, at times, the pressure on the water-wheels will be at least that due to the artificial head which results when the water is forced up into the standpipe.

A plant such as here described is that of the Albany & Hudson Railway and Power Company, at Stuyvesant Falls, New York. Fig. 1, on the next page, shows a standpipe in the above plant. The photograph was taken a moment after a large load had been instantly removed. The energy which is being gradually expended for several seconds in lifting the water out of the top of the standpipe would otherwise have been expended in a much shorter time on the water entering the water-wheels, and in the latter case would have resulted in an increase of speed beyond the power of the governor to control; whereas, with the standpipe as shown, the governor is able to hold the speed within permissible limits.

It was stated above that the spilling of water out of the top of the standpipe was necessary. There is one very effective way of preventing it. A relief valve having a venting area equal to that of the water-wheels may be placed at the base of the standpipe. It is hydraulically balanced, so that it will open under a very small increase of pressure, say, one pound per square inch more than the static pressure of the standpipe. When the water-wheel gates are suddenly closed, the relief valve will open and permit the escape of water which would otherwise be spilled out of the top of the standpipe. When the water-wheel gates are suddenly opened the balanced relief valve does not come into operation at all, and the water column in the standpipe gets in its work on the water-wheels while the nearly horizontal water column in the feed pipe is getting up to its new working velocity.

Many engineers who have experimented with relief valves condemn them for the very practical reason, found in their experience, that they will neither open nor close when they should. This, however, is due to the faulty design of the valve. Recent practice has shown conclusively that relief valves may be balanced so accurately as to be perfectly water-tight when not in action, and yet will open wide upon flume pressure rising a fraction of one pound per square inch above normal. Several relief valves in practical operation are of such large size that they have a venting orifice of 415 square inches, and in operation vent 148 cubic feet of water per second when they are wide open. The proper design of relief valves is a large

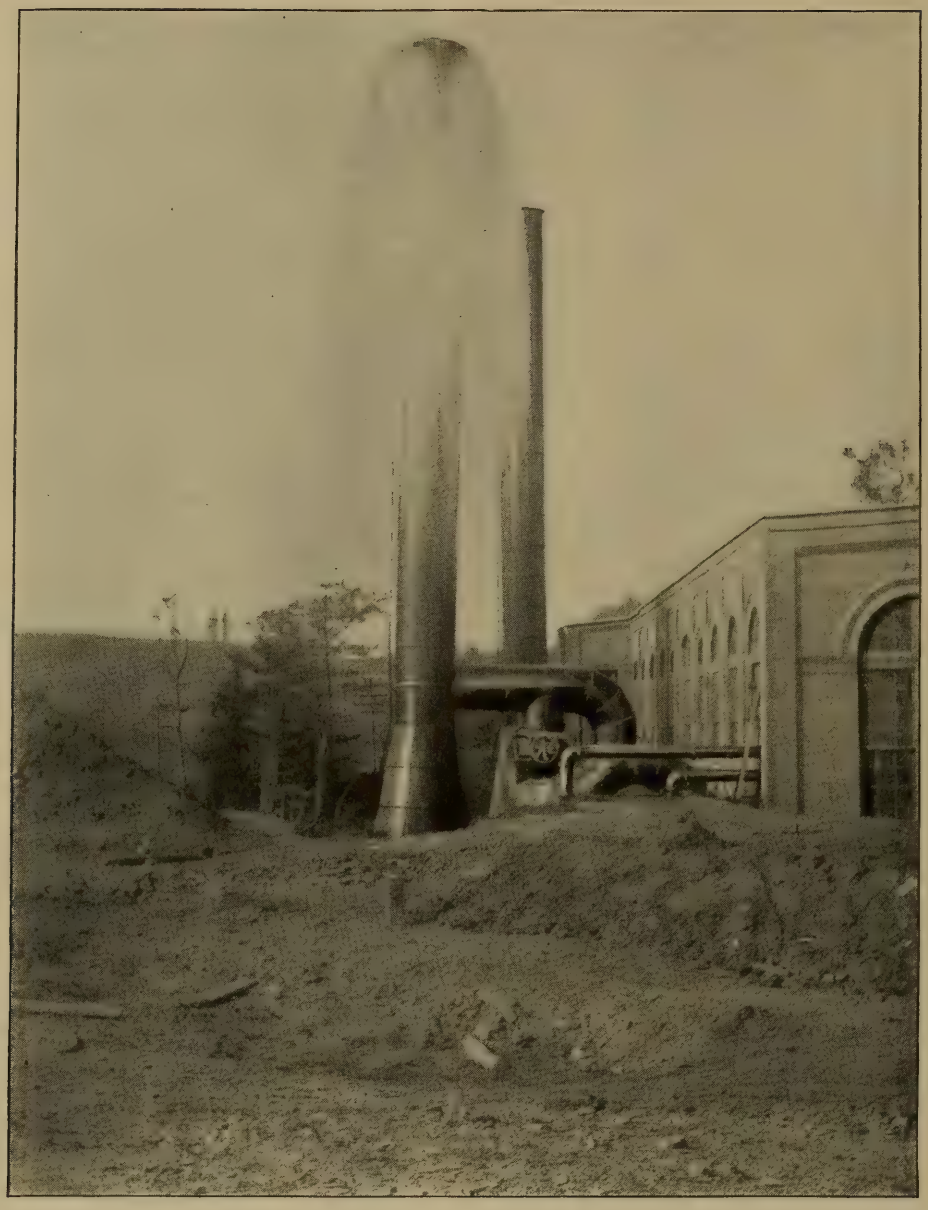


FIG. 1.—A STANDPIPE AT A WATER POWER STATION, SHOWING WATER SPILLING OVER THE TOP WHEN LOAD AND WHEEL GATE OPENING ARE SUDDENLY DECREASED

subject, and the limitations of this article will not permit of its elaboration. The obvious advantage of venting the water through the relief valve rather than out of the top of the standpipe is in the ease of disposing of the discharge water and the non-accumulation of ice in winter.

In some cases it is found that the ratio between the rate of acceleration of water in the feed pipe and the possible demand of water by the water-wheels is such that the governor can take care of loads going on suddenly, but that the kinetic energy in the water in the feed pipe will raise the flume pressure beyond the safety limit upon the gates being closed suddenly, and the ratio between the kinetic energy in the water in the feed pipe and the dynamic energy developed in the water-wheels is beyond the ability of the governor to control the speed. In such cases the standpipe may be dispensed with and the relief valve alone may be used. The plant of the Great Northern Paper Company, at Millinocket, Me., is arranged in this way.

In this plant there is a feeder 1100 feet long and 11 feet in diameter. At the lower end of it there are three pairs of horizontal turbines driving electric

generators, and also two small turbines driving exciters. Each of the generator units is provided with a suitable governor, and at the extreme end of the flume there is an hydraulically balanced relief valve having a circular discharge orifice 23 inches in diameter. This valve is so delicately balanced that the increase of flume pressure, due to suddenly closing part way the gate of one of the little exciter turbines, will cause it to open for a moment and vent a little water. Its maximum venting capacity is sufficient to take care of the largest load variations which can possibly occur, without letting the flume pressure rise more than a few pounds above normal. When we realise that the water column in this flume weighs 6,520,800 pounds, and that, when at working speed, it contains 2,226,000 foot-pounds of momentum energy, or 4119 horse-power-seconds, which must be expended somewhere before the water column may be stopped, it will be seen that the relief valve is not an unimportant part of the plant, and that its failure for one second to do its duty would result in bursting the flume.

The above named plant is also very interesting as an illustration of a water power which could be developed in no other way than by the use of very long, closed, steel flumes. There are five of these leading to the plant,—the one described above, and four others, 10 feet in diameter, which at this time, are being equipped in a manner similar to that of the first. Properly speaking, there is no natural water power, in the ordinary use of that term, at this plant, and an inspection of the country prior to its construction would not have revealed to the unpracticed eye any evidence to the effect that water power could be developed at that point. A few years ago no one would have dreamed of constructing a water power plant under such apparently unfavourable conditions. Its construction even now required a large amount of courage on the part of those furnishing the capital, and engineering of a high order on the part of those who planned the construction. The ability to control and regulate so large a weight of water under so high a head, and possessing so large an amount of kinetic energy in proportion to the dynamic energy it develops, is a practical object lesson which will undoubtedly bear fruit in the development and use of many water powers which are not now supposed to exist. In this plant the speed regulation is of so high an order that it is no exaggeration to say that there is no industry requiring power, no matter how large and sudden the load variations might be, which could not be successfully carried on in a plant of similar design.

Occasionally a water power of this general class is found in which the conditions are so unfavourable as to almost baffle the most carefully executed attempts to produce very fine speed regulation under large and sudden load changes. Fig. 2, on the next page, shows one of the most difficult plants to govern in the United States. The closed flume has several bends in it as it goes up the hill, at the crest of which is a standpipe. From this point the closed flume is comparatively level up to open water, which is 1500 feet away and 146 feet above the power house. The use of first-class governors, especially designed for the purpose, has made this plant capable of regulation under small load variations, but under very large and sudden load variations the speed cannot be kept within permissible limits at present. Much experimenting with relief valves has been done in this plant, but up to the present writing with only partially satisfactory results. It is believed, however, that sufficient data have been obtained to solve even this difficult problem, and that some changes which will be made when warm weather permits will render it possible to throw off and on large loads instantly without materially disturbing the speed.

From the wide range of plants which have been referred to it will appear that there is almost no natural condition under which water powers are found which cannot be developed so as to produce an operative plant. The broad lesson to be learned is, that the nearer we can

A DIFFICULT PROBLEM IN GOVERNING

approach to having our mechanical unit consist of a water-wheel, or wheels, placed in an open flume of ample proportions, the better will be the speed regulation, all other things being equal; and the further we go away from this simple design, the more difficult becomes the problem, the more complex become the devices necessary to obtain satisfactory speed regulation, and consequently the greater will be the expense.

DESIGN OF WATER-WHEEL GATES

A book of fair size might easily be written on this subject, and it is difficult to treat it briefly. The two things important above all others are,—first, make the gates work easily; and second, connect them in the simplest possible manner to the actuating part of the governor. So far as obtaining good speed regulation is concerned, experience has shown that equally good results may be obtained with either wicket, cylinder, or register gates. The last named gate is so rarely used at present that it will not here be considered.

Wicket gates of many designs have been used, and practice has shown that it is hopeless to attempt to obtain good speed regulation if the wickets are pivoted at one end, so that, as they open and close, they move like a door upon its hinges. These gates cannot be water-balanced. They sustain full flume pressure upon their outer surfaces, and when it is necessary for the governor to open them, in perhaps a second or two, something is sure to break. If they were constructed heavy enough to stand the strain, the connections and the governors also would have to be of such ponderous proportions as to carry the cost far above permissible limits. Makers of such gates usually provide worm gears to open them, and they are wise in so doing They could also open them with a jack-screw, and it would be found to be about as useful as the worm gear, if speed regulation is the end sought.

It is impossible for a governor to start from a rest and twirl a worm gear through twenty or thirty turns in a second or two, and stop it at the right place. Even if it did succeed in stopping it at an approximately correct position the momentum in the rapidly

moving parts, when suddenly brought to a rest, would break something. If a water-wheel gate requires a worm gear or a train of multiplying gears to open it, the wisest thing to do is to get another water-wheel. The writer knows of not a single case where good speed regulation under variable load has been obtained where such devices are used. This statement may be disputed by some.

There are, however, wicket gates which are pivoted at the middle. These gates, if properly designed, are nearly in water-balance in all positions, and they lend themselves most readily to the requirements of good speed regulation. A very good example of gates of this kind may be pointed out in the plant of the Niagara Falls Hydraulic Power and Manufacturing Company, at Niagara Falls. These gates are moved by pinions on their axes, worked by an internally cut gear which is rotated by means of a link and an eccentric placed on the shaft leading to the governor. This shaft turns but 120 degrees to completely open the gates. The gates are of a high order of design, and experience with them has fully demonstrated their utility. Notwithstanding the fact that they are subjected to the full pressure of Niagara Falls, they move with surprising ease at all stages of their opening. Gates of very similar design, but differently rigged, have been successfully used under very low heads. The spectacle of a wicket-gate turbine working under five feet of head, and driving an electric railway load at a practically uniform speed, is almost as inspiring a sight as that of a similar turbine driving a similar load under the full head of Niagara Falls.

Cylinder gates, if of proper design, are very well adapted to obtaining good speed regulation. The one thing necessary is that they be plain cylinders. Of late years some manufacturers have placed upon their cylinder gates fingers or lips reaching out between the guides, and by so doing have rendered their water-wheels very nearly ungovernable. A cylinder gate so built has the general shape of a top hat with notches cut out of the brim. Fig 3 shows such a gate

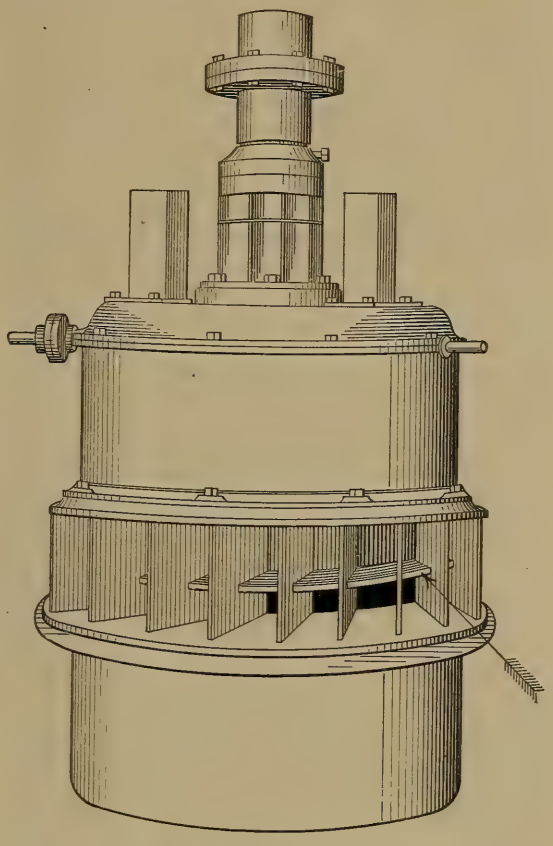


FIG. 3 —A CYLINDER GATE WITH FINGERS REACHING BETWEEN THE GUIDES

in position inside of the guides; the arrow points to one of the fingers, which in various makes of turbines are of different forms. Fig. 4 shows fingers recently cut from cylinder gates. The one to the left shows its

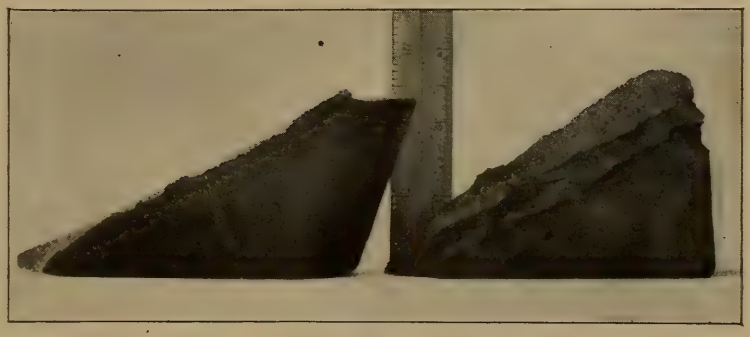


FIG. 4.-FINGERS CUT FROM CYLINDER GATES

lower side or the surface over which the water is supposed to pass in entering the turbine; as a matter of fact, the water touches but very little of this surface. The one to the right shows the upper surface, against which the water presses in its endeavour to enter the turbine. These fingers were taken from different makes of turbines, but in each case the hypothenuse of the triangle is the line of juncture between the cylinder and the finger. The one to the right shows the line of fracture plainly. Now let us examine into the effect of such fingers upon the question of speed regulation. These fingers stand directly in the path of the water as it approaches the turbine, and consequently the water presses against them and tends to close the gate violently.

The finger to the left in Fig. 4 was one of twenty-four cut from a single cylinder gate. Each of these fingers presented a surface of 9.69 square inches, or all of them a total of 232.3 square inches, in the path of the moving water. It was found by experiment that after the fingers were removed from the gate 4972 pounds less counterbalance was required to balance the gate, or, in other words, the water pressed down on each finger $4972 \div 232.3 = 21.4$ pounds per square inch. Theoretically, the pressure should have been equal to a head of twice that due to the water velocity. In the above case experiment showed that the pressure was equal to about three times the head due to the velocity, the discrepancy between the theoretical and measured values being chiefly due to the fact that the water did not approach the fingers perpendicularly, and the dead water between the fingers and the cylinder presented a larger area of pressure.

The practical side of the matter may be stated as follows:—It was desired to operate the turbine at a very constant speed, under large and sudden load variations. A well-designed governor, capable of developing 10,000 foot-pounds of energy in two seconds, was attached to this gate, but it was found impossible to govern the turbine. The very heavy counterweight which was necessary to balance the gate, of course, possessed inertia. It was found impossible to start and stop it quickly enough. When the counterweight, or part of it, was removed, the strain on the gate rigging and governor was so great that gear teeth were constantly stripping or shafts twisting off. Finally, the twenty-four fingers were all removed from the gate by the gentle persuasion of a hammer and cold chisel. At once all difficulty in moving the gate disappeared. The counterbalance, being no longer necessary, was removed, and the governor was able to produce a very accurate speed regulation under large and instantaneous load changes. The turbine, deprived of the fingers, has been, and is now, in continuous operation, to the entire satisfaction of the owner.

The manufacturer claimed that, by removing the fingers, the efficiency of the turbine was lowered; perhaps so, but carefully conducted tests, before and after the fingers were removed, showed that at all stages of gate, from one-quarter open to full open, just the same amount of power was developed with or without the fingers. Undoubtedly a little less water passed through the turbine before the fingers were removed than afterwards, but the difference was slight.

If there is any one thing which injures the susceptible feelings of water-wheel builders and rubs their fur the wrong way it is to talk in actual figures about the efficiency of their wheels. The writer has considerable data on this subject of the increase of efficiency obtained by the use of fingers on cylinder gates, but it is of a purely confidential nature and may not be published. The gist of the whole matter is that the very small amount of efficiency gained by the use of fingers is no compensation for the constant annoyance and expense which their use inevitably causes.

It should be kept in mind that whatever gain in efficiency is obtained by the use of fingers on cylinder gates depends upon the shape of the turbine. If the inlets between the guides are comparatively wide and shallow, the use of fingers adds little or nothing to

their efficiency, though they render the turbine ungovernable. Take, for example, the turbines in the Millinocket plant of the Great Northern Paper Company, previously mentioned. These turbines have wide shallow inlets and plain cylinder gates without fingers, yet they showed, in the testing flume, an efficiency of 85.9 per cent. at full gate, and an average efficiency of 83 per cent. at from three-quarters to full gate. This is certainly not a bad performance and they govern remarkably well. On the other hand, if the inlets between the guides are narrow and deep the use of fingers on the gates is of some use at part-gate. The purchasing public is more to blame in this matter than the water-wheel builders. The size of a turbine is usually designated by the purchaser in terms of diameter. If, for example, one make of 42-inch turbine is rated by its maker as developing more horse-power than another make of turbine of the same diameter, the purchaser is apt to choose the turbine which develops the most power, though it does not follow that by so doing he is getting more for his money. Also, the turbine maker is constantly urged by the purchaser to give a high rotative speed under low head. This also leads to a design of turbine which tempts the maker to use fingers on his gates. So many questions come into consideration in the selection of a turbine for any particular set of requirements that it is impossible to elaborate the subject within the limitations of this article. A better understanding of the subject by the purchasing public, and a willingness on their part to co-operate with turbine builders, will, undoubtedly, in the end do away entirely with the practice of putting fingers on cylinder gates.

Fingers on cylinder gates have been treated at length for the reason that they are the cause of more annoyance and more poor speed regulation than any other structural detail. It is gratifying to note that some water-wheel builders have entirely abandoned the use of fingers on their gates, and that others who have not quite reached that point are making strong efforts with their customers to induce them to have the fingers left off their gates. It is safe to say that at this time at least three-quarters of the cylinder-gate turbines under contract, or being installed in plants where speed regulation is a desideratum, are fitted with plain cylindrical gates without fingers.

DESIGN OF WATER-WHEEL GATE CONNECTIONS

This subject may be conveniently divided into two parts. First, the immersed connections, or those which begin at the gate and terminate in a shaft, or shafts, protruding from the water; and, second, those which begin where the former leave off and terminate at the governor.

As to the former, there are but two successful ways of connecting wicket gates, one being that already described as in use in the plant of the Niagara Falls Hydraulic Power and Manufacturing Company. Such connections are usually of bronze, and, if well-designed and built, give uniformly good satisfaction. This design is more often employed under high heads. A more usual method is to connect the outer ends of the wickets, through links, tangentially to a circular member which is rotated around the turbine axis by means of a lever terminating in a gear sector which engages a pinion on the shaft protruding from the water. This is a very common practice, and where the parts are of fair design and construction it gives very satisfactory results. Scores of thousands of horse-power of wicket-gate turbines, rigged in this manner, are in operation, and are giving admirable results. Connections of this kind necessarily have a good many small, moving parts, and builders in the past have perhaps erred in making them too light for the requirements of modern speed regulation. They should be strong and rigid in construction and all pivotal parts carefully fitted. It may seem absurd, but the writer has seen, within two years, the radial arms connecting the wickets to the banjo of a turbine, sold for use in an electric power plant, connected by

means of carriage bolts. It is perhaps unnecessary to add that it did not take long for these gates to come to an untimely end. It is, however, gratifying to note that some makers are now building wicket gate connections in a very thorough and substantial manner.

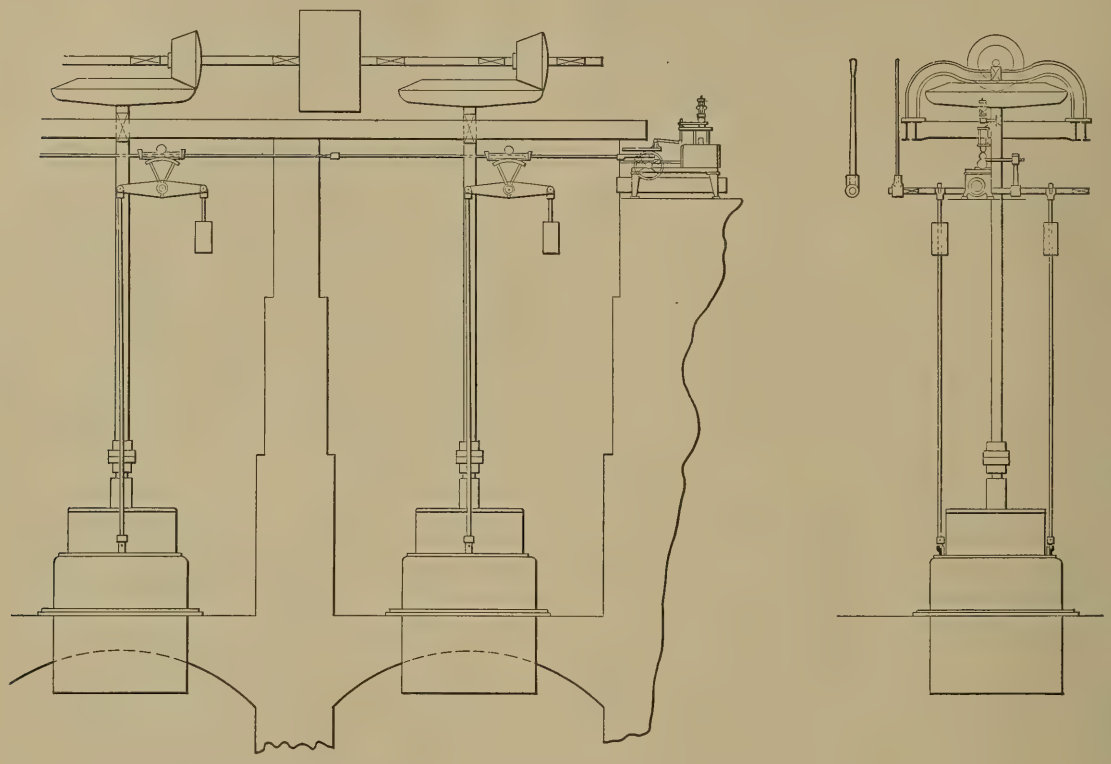


FIG. 5 —A GOOD METHOD OF CONNECTING THE GATES OF SEVERAL VERTICAL TURBINES

Cylinder gates, as now built, are almost universally moved by means of two draw-bars terminating in racks which engage pinions on a shaft perpendicular to the turbine axis. Until quite recently these racks have been immersed, and the pinion shafts have been connected through bevel gears to a shaft parallel with the main shaft and protruding from the water. This method is open to the objection of having gear teeth under water, subject to corrosion and obstruction by bits of wood floating in the water. At present some builders are bringing the draw-bars out of flume heads through stuffing-boxes, and placing the racks and gears in the air. The objection to this is the difficulty which water-wheel builders seem to experience in getting the pitch line of their gears on the axis of thrust. This appears to be merely a question of design, and will, undoubtedly, be overcome. The writer is inclined to the opinion that, all things considered, the method last described is preferable, though it must be admitted that in some of the largest and most successfully operated plants, as, for example, that of the St. Anthony Falls Water Power Company, previously alluded to, the racks and gears are immersed.

Probably it is near the truth to say that either method will give good results, from the standpoint of speed regulation, if care be exercised in the design and finish of moving parts. Builders, as a rule, have erred in making connections of this kind too heavy. The general idea seems to have been to get in as much material as possible, in the hope of making things strong. This is an error. These connections have to be started, stopped, and perhaps reversed in motion, in very short spaces of time, and practice has shown that massive gate connections have frequently failed from their own inertia in places where they were, later, replaced by lighter, but better designed, parts, which gave good results.

The writer has found that cut gears of four, or occasionally three, diametral pitch and 2½-inch face are heavy enough for rigging in air, and also for most immersed gears, if made of bronze. Occasionally, immersed gears of three, or even two, diametral pitch, may be necessary, but such cases are rare. The above statements are not in accordance with the usual practice of water-wheel builders, but the advisability of using gears of the proportions above named has been demonstrated in hundreds of cases. Sometimes the form of the gear teeth is so bad as to render the entire rigging incapable of prompt and certain operation. There is, of course, no excuse for this.

The rigging between that usually furnished by the water-wheel builder and the governor is very difficult to treat in a general way, for the reason that the location of the governor is usually fixed by the space available for it and the location of surrounding objects.

In connecting up several hundred governors it has been found that rarely can the same connections be used. Experience has been the only teacher in this matter, and that which has been learned has been chiefly those structural details which should be avoided. In plants of low head where the electrical units are large, it is frequently found necessary to actuate the gates of several vertical wheels working as one mechanical unit by means of one governor. Several ways of rigging such wheels have been tried. The common method has been to place two racks on the top of each gate. These engage a pair of pinions on a horizontal shaft directly over the turbines and perpendicular to its axis. The end of this shaft carries a bevel gear engaging another on the bottom of a vertical shaft. The tops of these four vertical shafts are then all connected to one general gate shaft placed horizontally, parallel with the line shaft, and directly below the crown gears. To this shaft the governor is attached.

This method has never given satisfactory results. For four turbines thirty-two gears would be required. The gear friction is so great that the whole system is sluggish, and fails to respond quick enough to permit of good speed regulation. But by far the greatest difficulty experienced with such a rig is in the twist which takes place in the long, horizontal gate shaft whenever the governor moves. This causes the gates nearest the governor to move first, and those further away to come along with great deliberation. The result of this is that the gates nearest the governor are invariably carried too far, and when the more remote gates come up to correct position the average gate opening is too great or too small, as the case may be, and the governor has to make another move. This action would be kept up unceasingly. It was found by experiment that to obviate this difficulty the long, horizontal gate shaft would have to be of prohibitively large diameter.

A more recent and better design is to connect the upper ends of all the vertical draw-rods to radial arms on a long, horizontal shaft, placed, as before, parallel with the line shaft and below the crown gears. Opposite to each radial arm, connected to a draw-rod, was placed another radial arm carrying at its end a weight equal to that of the weight of the gate. This method eliminated all gears except one rack and gear connecting the general gate shaft to the governor. The only difficulty with this design was that it was still subject to the twist in the long shaft. However, turbines may be successfully governed in this way. In one plant sixty turbines, in ten units of six each, each unit having one governor, are in successful operation, the speed regulation being very satisfactory.

But the most successful method of connecting up such gates is shown in Fig. 5. It will be noticed that each pair of draw-rods is connected to a pair of walking beams, which carry counterweights on their opposite ends. Each walking beam carries a gear sector which engages a rack on a long, horizontal reciprocating member terminating at the governor. The racks on the

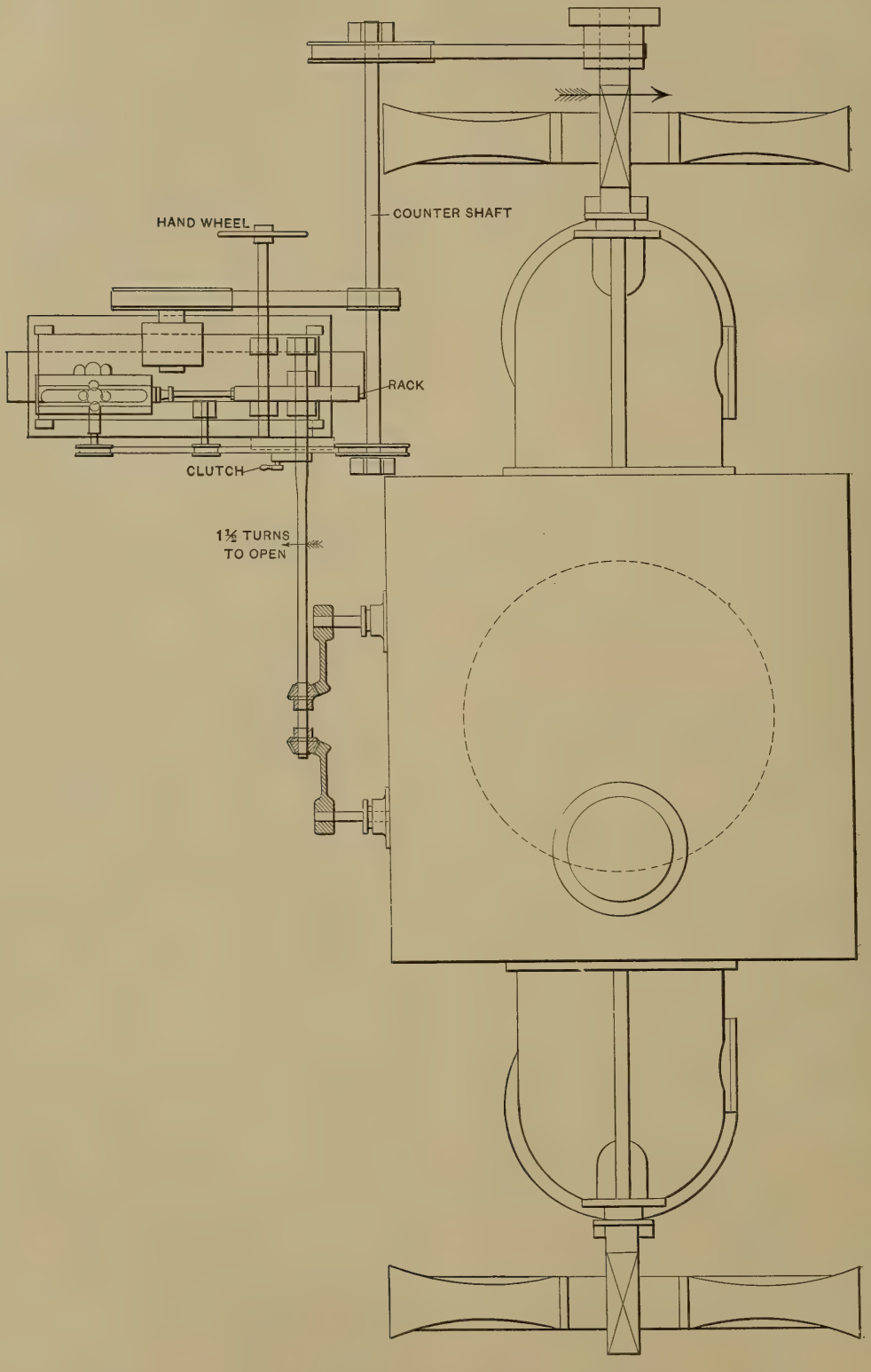


FIG. 6.—GOOD PRACTICE IN CONNECTING A GOVERNOR TO A PAIR OF HORIZONTAL WICKET-GATE TURBINES

reciprocating member are "sleeved" on it, and held in place by pins, which may be removed if it is desired to disconnect any turbine from the governor.

By this method any one, or any combination of turbines, may be handled by the governor or any turbines by hand, at will by means of a lever shown in the end projection. It will also be noted that there are no twisting strains in the long shaft, the only strains being those of extension and compression, which may easily be provided for. This design is being used in two large and important plants now being built.

Fig 6 shows one good method of connecting a governor to a pair of horizontal wicket-gate turbines. It will be noted that the shaft connecting the two gear sectors on the gate stems goes directly to the governor, and is connected to it through a pin clutch which may be opened, and a hand-wheel on the governor may then be used to move the gates by hand. The only improvement on this design which can be suggested would be to eliminate the countershaft between the governor pulleys and the turbine shaft by placing the governor beyond the draught-tube quarterturn, so that the governor pulleys might belt directly on to the turbine shaft. The limitations of available space prevented the location of the governor in this manner on the drawing which shows the design used for three units in a modern power plant.

Frequently the only possible location of the governor prevents anything like direct connection between it and the turbines. In such cases experience has shown that it is wisest to avoid the use of several pairs of bevel gears and long shafts, and in their place use a steel rope drive. This method has great flexibility, and permits of governor locations which would otherwise be impossible. Fig. 7 shows a design of this kind. The governor is located in the only available space in the whole building, and yet its connection to the turbines is perfectly adequate. The steel rope used is small in size, made of very small wire, especially laid up, and its ends are fixed to the grooved sheaves, which are provided with internal take-ups, so that the rope may be kept tight as a fiddle string. This general method of connection is in successful use in many plants where the requirements for speed regulation are most exacting.

Examples of different methods of connecting governors to turbines might be multiplied almost indefinitely, each illustrating features of interest. In the few which have been shown it will be evident that the two ends which have governed the design are simplicity and directness. These two things should never for a moment be lost sight of, and the more completely they are embodied in the design, the better will be the speed regulation. To these two may be added another, and that is freedom from lost motion. These three things are absolutely necessary if successful results are to be expected. The slightest motion of the governor must be transmitted in the simplest and most direct manner, and in the shortest possible interval of time, to the turbine gates.

WATER–WHEEL GOVERNORS

From the considerations which have been advanced it will be seen that, even under the most favourable conditions, the water-wheel governor has a difficult duty to perform, while under the unfavourable conditions frequently found it is called upon to do more things in a shorter space of time than often falls to the lot of a machine. We are confronted at the start with the proposition that the governor is supposed to hold the speed of the turbine constant, but that it does not begin to perform its work until after the speed of the turbine has begun to change; hence, an absolutely perfect speed regulation can never be obtained with a governor which depends upon centrifugal force in rotating balls or weights. All governors which have come into practical use are of this general type. Even after the goveror has moved the gates the water tends to enter them at a higher or lower velocity than normal; the governor must, therefore, be able to think. It must know

enough to stop the gates short of, or carry them beyond, the position indicated by the change in position of the centrifugal balls. It must be able to do this no matter how large and sudden the load change, or how sluggish the water column may be, or how large its momentum energy may be in proportion to the dynamic energy it will develop in the turbine. To accomplish this has been the aim of inventors ever since the use of electric power created a demand for constant speed, and roused other users of water power to the advantage to be derived from good speed regulation.

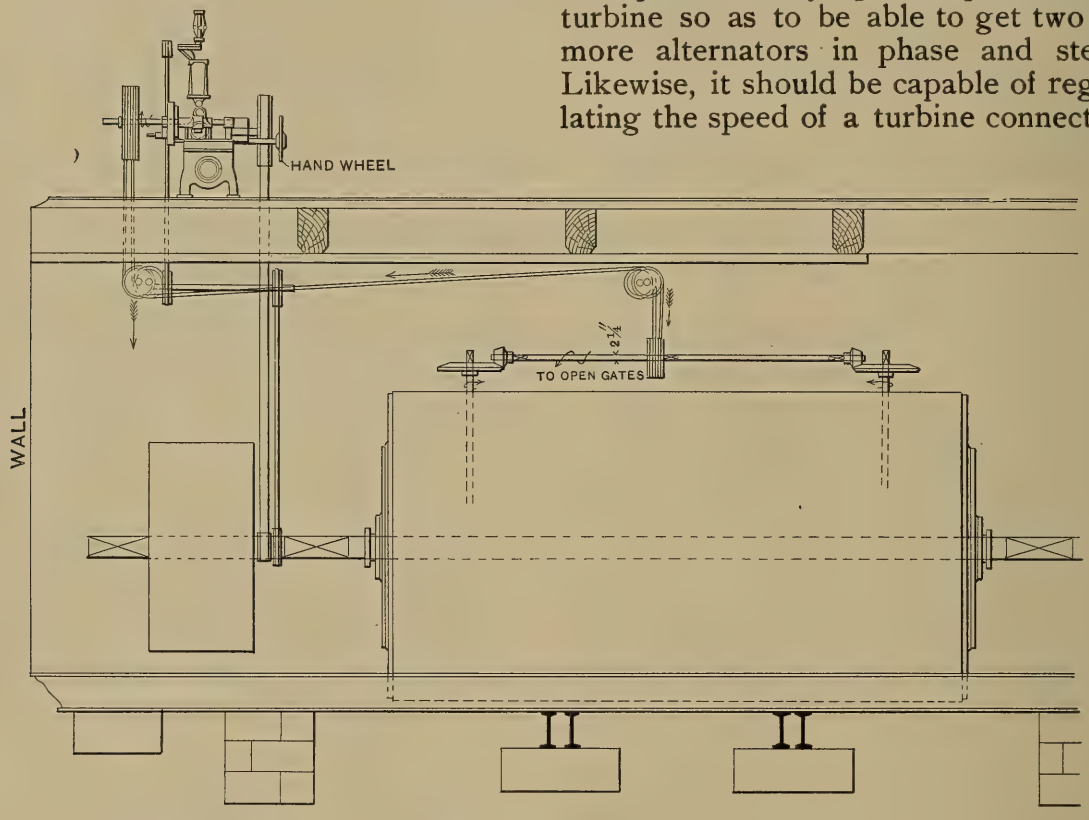


FIG. 7. -CONNECTING UP A WATER-WHEEL GOVERNOR BY MEANS OF A STEEL ROPE DRIVE

The governor must be able to start from rest, move the ponderous gates of the turbine to the correct position in a very short space of time, and come to rest as promptly as it started. A good governor should be able to move the turbine gate to its correct position in one or two seconds upon large load changes taking place, and in a correspondingly shorter interval of time for small load changes. It should be of such design that several turbines, working as independent mechanical units, may drive electric generators run in parallel without their tending to unequally divide the load. It should also be capable of varying the speed of the turbine so as to be able to get two or more alternators in phase and step. Likewise, it should be capable of regulating the speed of a turbine connected either mechanically or electrically with a steam-engine, so as not to unequally divide the load nor disturb the steam-engine. It should be of such design that, in event of the belt between the governor balls and the turbine shaft breaking, or being thrown off by a malicious person, the governor will quietly close the gates and bring the plant to rest instead of letting it run away.

How far these various difficult functions have been embodied in machine design may be illustrated by the fact that over 250,000 horse-power of turbines are at the present time accurately governed by one make of governor alone. No attempt will be made here to compare the merits of the different makes of governors now on the market. To do so might not be appropriate for the present writer, and the intricacies of design are such that the attempt

could not but be tedious. Neither will it be attempted to review historically the development of water-wheel governors from their first crude form to their high stage of development at the present time. Nor will it be attempted to discuss nor criticise the curious theories of governing and more curious mathematics of the subject which have appeared from time to time. The few simple facts which have been presented have been taken entirely from the experience of actual practice, and everything which belongs to the hoped-for achievement of the future has been rigidly excluded.

In conclusion, it may not be amiss to say that experience has abundantly proved that if care be taken in a proper selection of turbines, governors, and auxiliary appliances, and if thought be given to the design of the steel and masonry which conduct the water from the pond or open forebay through the turbines to the tail-race, few, if any, water powers are of such natural conformation that they may not be developed into plants which will satisfy the most exacting requirements for speed regulation.

The governing of plants in which tangential or impulse water-wheels are used is an interesting subject, pregnant with much recent practical experience. The writer regrets that the length of this article, which has already exceeded proper limits, prevents its being here discussed.

THE COPYING OF AMERICAN MACHINERY

AS AN ENGLISHMAN SEES IT

By Joseph Horner

WHEN a really good thing is put on the market, some people imitate it; others try to go a point better. Some, wedded to ancient ways, do not, or will not, see much in it, until they find themselves and their interests hard hit by the innovation. These represent the various attitudes of British manufacturers towards American machinery.

It is well, in the interests of a nation's industries, and of the highest national and industrial life, that the burden of the human drudge shall be lessened to the last limits. At the present time, from that point of view, America occupies the foremost position. Ten years ago little of the automatic machinery which has been so highly developed in that country was known in Great Britain, outside of the small arms factories. Half a dozen years since it was finding its way into the cycle shops. Now it has found a welcome in many of our leading engineering establishments that were destitute of it five years ago.

The result is, that British machine tool makers are copying much of this machinery when it is not protected by existing patents. In some instances resemblances are so close that it would be difficult for anyone not an expert to detect the difference between the original and the copy. In numerous cases, however, British firms have produced modified types, which, while possessing the essential elements embodied in the original machines, have details worked out differently. In some instances the copies are real improvements on the American originals; but these are exceptional.

American machinery has made its way here in spite of the strongest prejudices. I have heard scores of practical men denounce it, much as they do the German to-day. I know firms, too, who, having vented their antagonism in

spiteful terms against American machinery, have afterwards laboured with feverish haste to copy, and, if possible, to improve upon it, for sale in Great Britain. The number of firms who now manufacture machines which are modelled after those of successful American types is constantly increasing, and a considerable business is now being done with these in this country. These efforts, however, do not result from any love which was borne to American designs in the first place, but because of the pressure of their competition which is making itself felt here.

Neither is it in Great Britain alone that American machinery is being imitated. The recent Paris Exhibition was an eye-opener in this respect. Many of the leading Continental firms have adopted American designs, sometimes absolutely, in other cases in the matter of certain details only.

The two main reasons why these machines are imitated are either because they produce more cheaply than those which they displace, or they yield more accurate results. But a cheaper and a better product also often go hand-in-hand as the result of employing the best modern machines. The following are a few of the more notable examples of British imitation of American inventions.

To cut a long screw in a British lathe, a certain number of toothed, or cog-wheels, have to be set up by the workman,—a different set also for every different class of screw. This change of wheels seldom occupies less than fifteen minutes, and may take half an hour. It is repeated many times a day in a large shop. A few years ago an American devised a permanent arrangement of wheels by which the changes for different screws could be effected within a minute by the simple movement of a handle. This excellent device is now copied on several lathes, both British and Continental.

Machines for making small screws in large quantities, in place of producing them singly by the older and inaccurate processes, were invented and highly developed in America before British firms took them up. The Cleveland, the Hartford, the Brown & Sharpe, the Spencer, the Acme are American machines, nearly as well known now in Great Britain as in the States. The marvellous economies of these are scarcely conceivable by those who have not witnessed their rapidity of operation; and though designed primarily for making screws, any other class of small work, involving turning, screwing, boring, and so forth, is done upon them cheaper than in any other way.

A leading American firm was producing brass collar studs on a screw machine at the Paris Exhibition. These studs were being turned off at the rate of two and a half a minute, or 1500 in a day of ten hours. Each one involved the separate action of six tools, and included stamping the firm's name upon each stud, after which they were delivered by the machine, cleaned from chips and oil, for presentation as souvenirs to visitors. I was informed that machines of this class had been designed to run quicker than the earlier types in order to meet the demands of the German clock makers, who had bought several hundreds of them.

Yet 1500 articles for a day's work is not by any means a big record with regard to number, because six tools have to come into operation. In cases where fewer tools are used, plenty of instances could be given of the product of such a machine ranging as high as 5000 pieces in ten hours! On another type of American machine,—the "Acme,"—the day's work has run as high as 9600, or nearly sixteen a minute! The makers of this last machine execute orders on curious terms. A customer sends brass rod to the factory to have screws made from it. He receives his screws, and leaves the brass chips only as payment!

American screw machines are stocked and sold by dozens of British agents in London, Birmingham, Manchester, Glasgow, and other big cities. Many hundreds of them are found in British shops. They are being imitated by our manufacturers and in nearly every Continental country, copied, in some cases, very closely; in others, with variations. But the American machine

still holds its place by very long odds. In turret machines several tools are caused to operate in rapid succession on a piece of work by the turret, or capstan,—a device which is applied to turning lathes and to screw-making machines. In place of the single tool used in a common lathe, six, eight, ten, and in a few instances as many as twenty tools are taken in charge by a revolving turret which brings them round, each to fulfill its own proper function at the exact instant when it is required to come into action. Each tool fulfills its own distinct duty, and the result is, that when the turret has revolved once, a single article of manufacture will have had the half-dozen, dozen, or more separate cutting operations performed on it necessary for its completion. In some instances two separate pieces will be produced during a single rotation of the turret.

This device also originated in America previous to the middle of the last century, and that country reaped the solid advantages of its successful employment for many years before British firms saw much in it. When the manufacture was at last taken up in Great Britain, it remained in a crude form, while American firms still went on improving until they made the movement of the machine wholly automatic. Now many British firms are wisely following that example with beneficial results. But here also much leeway has to be made up.

Toothed, or cog-wheels, are used in very large quantities in machinery. The common British practice has been to cast them roughly and inaccurately from patterns; the American, to cut the teeth cleanly and truly from solid iron, steel, or brass. In the exceptional British practice the machines designed for cutting teeth have, until very recent years, required the constant attendance of one man, and the majority made do so now. American machines, on the contrary, are so constructed that the attendant need not come near them from the time of putting in the wheel which has to be cut until all the teeth are finished. The machine rings a bell to let him know when the work is finished, and then it stops forthwith. I was in a shop the other day where a machine of this kind was left to run all night, doing work without any attendance.

The bevel cog-wheels that drive some of the chainless cycles afford a remarkable illustration of the highest specialisation in this line of American manufacture. For cutting the teeth of these a special machine, which I have seen in operation, has been designed. Any number of wheels can be cut in it, all exactly alike, and absolutely correct, without any attendance, save that of putting the pieces in the machine and taking them out again. But these machines are built to cut one kind, and one size of wheel only, and no other.

Slowly, and but very slowly, are British firms awaking to the importance of good cut wheel teeth. Only a very few firms here as yet make high-class machines for this work. They cannot imitate the latest and best American machines, for they are covered by patents. The automatic types, therefore, which are used in the best British shops to-day still come chiefly from the United States. This case is paralleled by that of the gauges for measurement. The Americans have got a big headway, and have acquired so much and so rich experience that it seems nearly hopeless to try to oust them from their supremacy in this line. Certain Continental firms also have developed the manufacture of gear-cutting machines more highly than the British firms have done, and they, too, will have to be counted on in the years to come.

A milling machine is one in which rotary cutting tools are employed. Improved and developed in scores of forms, it is the most important machine tool, the lathe excepted, in the American shop. Its keen, strong, tireless cutters will tear off great, curling, stubborn chips of hard steel, or the finest films. Imagine a small circular saw increased in thickness to several inches, and you have the typical milling cutter which has supplanted the single cutting tool. It matters not how large or how small the work, whether a width of one inch, or one of twenty-four inches, it is all the

same, for machines are made to take it. Two years ago most British firms looked askance at this milling machine; it is even now distrusted in some of our shops. Even in many of those where it is appreciated and used, it is not employed to one-half, indeed, one-fourth, of the extent to which it might be with advantage. Thousands of these machines have come across from the United States, and hundreds, modelled on identical lines, are being made to-day and offered for sale by British tool makers.

Machines, too, for grinding tools, gauges, and the finest class of work to precise dimensions, were developed in America long before British firms took up their manufacture. The wonderful precision of these machines is such that it is easy to grind work on them definitely within a thousandth part of an inch, and less, to actual measurement. The spindles of many rotate at speeds ranging from 10,000 to 30,000 times in a minute. In some specially fine machines they will make 100,000 revolutions in a minute! And some of these highest American types are not yet copied here. When a British shop is advanced enough in its ideas to require such machines the order goes to America.

It would be easy to speak of other classes of work in which America has led and Britain is toiling after. Mention only may be made of the application of electricity to the driving of machines; that of compressed air for actuating drills, hammers, cranes, and much besides; of certain types of hoisting machines which are quicker in action and more adaptable than our own; of machines for foundry work, for woodworking, for boot and shoe making, and much more. But space forbids.

In conclusion, the question arises whether the British imitation of American rivals will save the situation. Imitation is the sincerest form of flattery, and yet this may not prove to be an unmixed good. Possibly it may not be the most excellent way in the end.

British firms appear to believe that, by copying improved machines, they will always be able to retain or recover their menaced position. Those who do this,—buying a machine, pulling it to pieces, and imitating it,—forget that though it is easy enough to imitate, lost trade is not regained in that way. Imitators generally fail. Britain's supremacy was not won thus. She led the van. America is not gaining ground by following Great Britain, but by getting ahead of her.

Further, if a firm, having found its business damaged by the superior designs of a rival, endeavours to regain that business, it becomes the proverbial stern chase. The problem, then, is not that of making goods as well as one's rivals, they must be better, or cheaper, or both. And, again, the firm which is already in possession of a market holds the best position for its retention.

The firm or nation, therefore, which has a good start of its rivals will have the better chance to hold its own. This is the case now with the leading American makers of machine tools. They have secured a good market in Great Britain and abroad. In a dilatory way British manufacturers are waking up to the gravity of the situation, and are offering rival tools, of a class similar to those which find a ready sale here. But the necessity for producing something better still is generally neglected; and while they imitate existing machines, the American firms advance, constantly devising improved forms. While British firms are panting to recover lost ground, the Americans are still forging ahead, and scoring new triumphs year by year.

STEAM BOILERS AT THE PARIS EXHIBITION

SOME CONTINENTAL TYPES

By W. D. Wansbrough

OVER half a million pounds of water per hour converted into steam of twelve atmospheres pressure by two great batteries of boilers,—ninety-one generators in all,—of types the most diversified, exemplifying the best practice of the leading Continental makers,—and yet an exhibit almost deserted, save for the occasional and involuntary presence of bewildered strangers in search of,—well, of anything, rather than the actual source of all the power and light so lavishly in evidence throughout the Exhibition! Nevertheless, the extraordinary variety in type and structure of the boilers themselves, no less than the extent of the installation as a whole, stamped the boiler houses with a lasting interest to every person concerned in the application of steam power to electrical or industrial uses.

By the courtesy of the makers, who, with one or two exceptions, placed full particulars in the writer's hands, he is enabled, in some degree, to put upon record the main features of this unique collection of steam generators. The well-known Niclausse water-tube boiler was strongly represented, appearing in five separate classes, namely, that of industrial purposes; heating and ventilating; traction; merchant marine and yacht boilers; and naval. In the first class they contributed, by their four groups of three boilers in the French section, and their three groups of three boilers in the foreign section (Fig. 1), a total of 77,000 pounds of steam per hour to the department of motive power. The Niclausse boiler differs from the general type, which we may characterise as the Babcock & Wilcox pattern, with its numberless variations by different makers, in that the back headers are dispensed with, the heating tubes being closed at their extremities. The front headers are double, the front chamber of each communicating only with the inner or circulation tubes. Through these the downward current of water flows from the drum overhead, and is delivered at the further end of the generating tubes, the heated current of water passing through the back compartment of the header into the drum again.

The grate is of the same length as the tubes, and the products of combustion pass continuously upward towards the chimney, not being baffled, as in the ordinary water-tube boiler. In the Niclausse boiler access is not required to the sides or back, every part being easily got at from the front. Fig. 2 shows the manner in which the water circulates, and in Fig. 3 the actual construction of the various details is clearly seen. The builders, Messrs. J. & A. Niclausse, of Paris, draw attention to a recent improvement of theirs, the object of which is to substitute stamped steel for malleable iron in the different parts of the boiler. This year they intend to produce the collectors, or upright headers, —see Fig. 3,—in steel by the use of weldless rectangular tubes, solid-drawn, and stamped to the form shown by hydraulic pressure. The British makers of the Niclausse boiler are Messrs. Willans & Robinson, Ltd., of Rugby, while in the United States the boiler is built by the Stirling Company, of Chicago.

The Société Anonyme des Générateurs Mathot, of Rœux-lès-Arras, showed a large group of seven water-

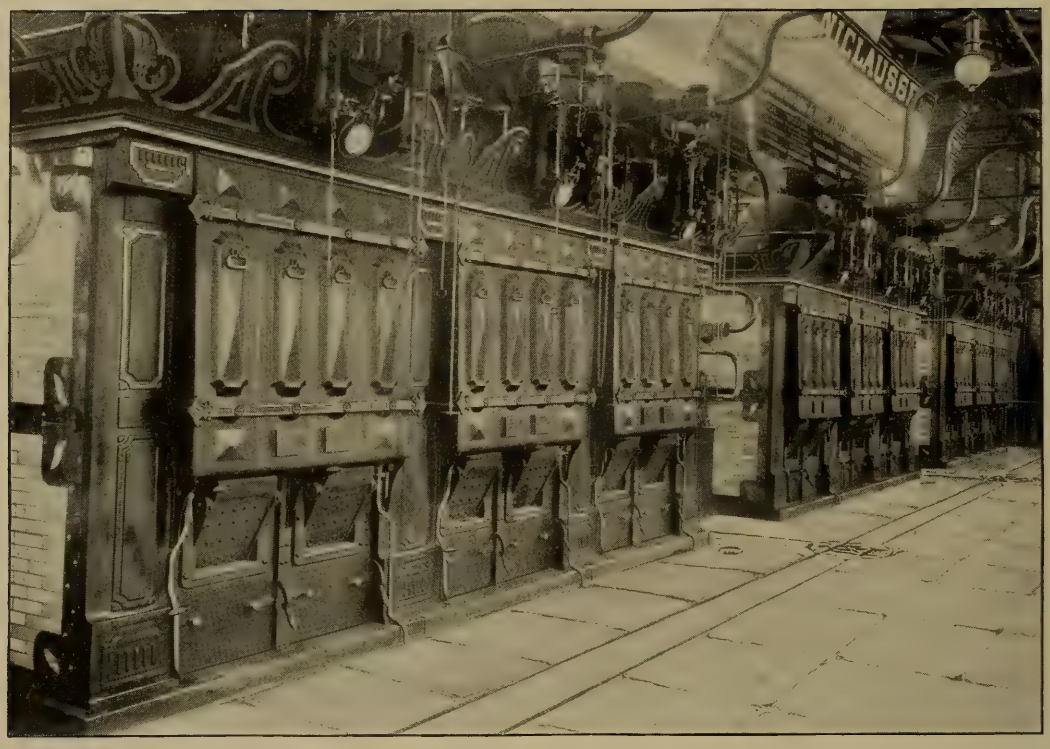


FIG. 1.—NICLAUSSE WATER-TUBE BOILERS. BUILT BY MESSRS. J. & A. NICLAUSSE, PARIS. THE BRITISH MAKERS ARE MESSRS. WILLANS & ROBINSON, LTD., RUGBY, ENGLAND, AND THE AMERICAN MAKERS, THE STERLING CO., CHICAGO

tube boilers, and were also the makers of the steam pipe connections for the motive power plant. The heating tubes, of wrought iron or steel, are fixed into tube plates in the front and back water chambers, which in so many of the exhibited boilers took the place of the tubular "headers" familiar in British and American practice. It is in the method of disposing of the products of combustion that the principal peculiarity of the Mathot generator consists. Figs. 4 and 5 will show clearly the departures from the ordinary, or non-Mathot practice. In place of the approximately vertical diaphragms, or baffle-plates, causing the flame and gases to pursue a serpentine course, we have, as shown in Fig. 5, two baffle-plates, lying at the same angle as the tubes themselves. In this arrangement (introduced in 1895) the two lower ranges of tubes are alone exposed, for a great part of their length, to the radiated heat from the fire and gases, in place of the latter being abruptly cooled by traversing the whole depth of the system of tubes.

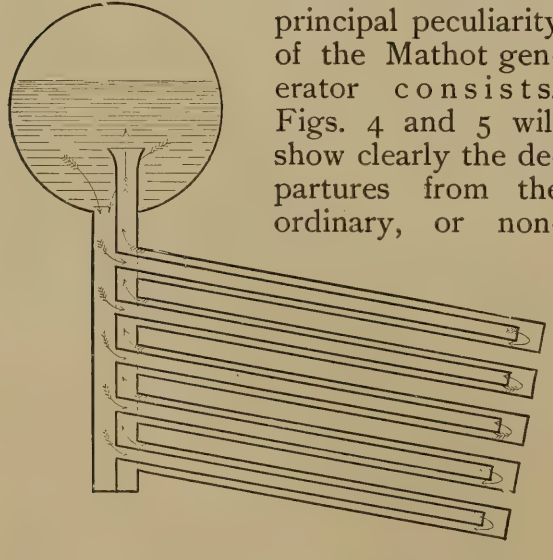


FIG. 2.—DIAGRAM SHOWING THE CIRCULATION IN THE NICLAUSSE BOILER

The makers claim that more complete combustion is ensured by their method of turning the draught backwards and forwards in a direction parallel with the tubes, finally impinging upon the bottom of the drum. Another difference is that the front and back water chambers rest upon brick pillars and carry the weight of the drum, instead of being suspended from it, as is usual. The makers comment strongly upon the stress that, in the latter case, is thrown upon the fastenings of the inclined headers, or water chambers, where they are attached to the drum, owing to the

weight of the tubes and their contained water. This tends to force the headers into a vertical position, a source of danger which they claim to have eliminated in their boiler.

The Babcock & Wilcox Company exhibited, through their Paris house, a total of fourteen boilers, eight of which are shown in Fig. 8, these being mechanically fired. The construction of the Babcock & Wilcox boiler is so well known that an extended description is unnecessary. Fig. 6 shows the general arrangement, and Fig. 7 an enlarged view, in section, of the water tubes, headers, and connections to the steam-and-water drum.

The principal elements consist essentially of three parts, each connected with the others, and in each of these the process of steam-raising is carried on. First comes a series of lap welded wrought-iron tubes, expanded at each end into sinuous, vertical collecting boxes, each containing one zigzag row of pipes. In these tubes the water, divided into small volumes, is quickly heated, and rises through the sinuous headers, at the front end, into the second element, the large cylindrical vessel or drum, where the steam separates from the water, the latter returning again through the vertical tubes at the back end into the inclined water tubes, where it is again subjected to the action of the fire, and again passes into the drum. Thus a continuous and rapid circulation is kept up, and a uniform temperature is maintained throughout the boiler.

The third element is a mud-drum, or collector, attached to the lowest point of the inclined water tubes, and into this the matter held in suspension in the water is, to a large extent, precipitated by its greater specific gravity as the water descends through the vertical tubes and tube-boxes at the rear. A large and continuous waterway through all the parts is secured by the end connecting boxes being attached to the drum by short tubes expanded into accurately bored holes. The mud collector alone is made of cast iron, a special mixture being employed, that metal being found to resist corrosion best. Four of the exhibited boilers were of the marine pattern, differing somewhat in detail from those above described.

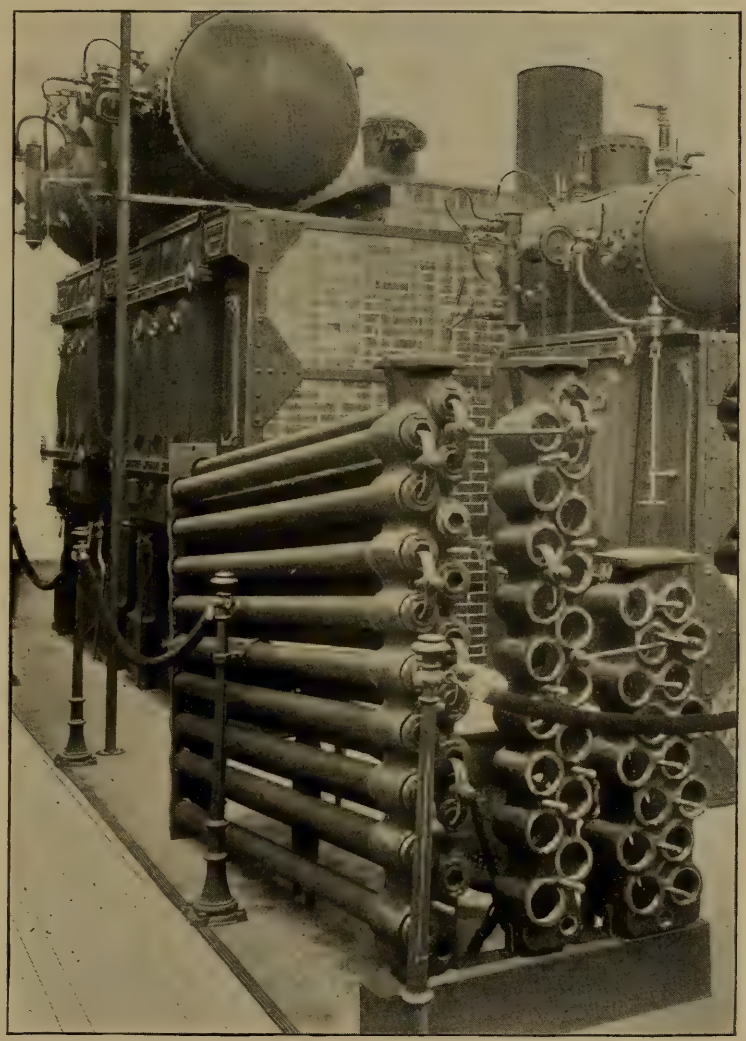


FIG. 3.—NICLAUSSE BOILER DETAILS

The Fives-Lille Company showed a group of three semi-tubular elephant boilers, each of 2260 square feet total heating surface, and 56½ feet grate area. The construction of this well-known French type of boiler is that of

a large cylindrical upper vessel, penetrated by 102 four-inch tubes, and joined by short vertical tubes, or water-legs, to two much smaller cylinders beneath exposed to the direct heat of the fire. The whole is enclosed within a brick

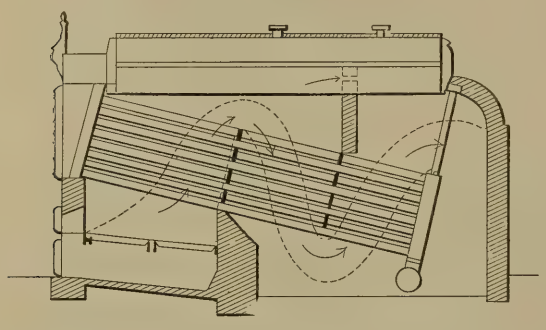


FIG. 4.—USUAL COURSE OF GASES OF COMBUSTION IN WATER-TUBE BOILERS

furnace, the flame and gases first enveloping completely the lower tubes, thence returning in contact with the external surface of the upper boiler, and finally passing to the chimney through the small tubes in the latter. The lower boilers are detachable from the large or upper boiler.

M. Antonin Montupet, of Paris, showed a group of five water-tube boilers and one elephant boiler, all fitted with special appliances for accelerating circulation, and, together, capable of vaporising 33,000 pounds of water per hour. Space does not permit of sectional illustrations of all the boilers, but Fig. 9 conveys the general idea of the water-tube design. It will be seen that the inclined tubes are closed at the rear ends, very much as in the Niclausse generator. The circulating arrangements are best seen by reference to the enlarged detail in Fig. 10, which shows a section of the upper reservoir or drum. This may be transverse or longitudinal, according to the space at disposal. Riveted to the drum is the wrought-iron case *BB'*, with compartments *D* and *E*, formed by the partition *C*. The inclined heating tubes *T*, of length to suit the circumstances, are fixed both in the partition and in the back plate of the casing. The simple tools by which these tubes can be inserted or withdrawn are shown in the small Figs. 11 and 12.

The tubes have holes cut in them above and below between the two plates, thus communicating with compartment *E*. An internal circulating tube *t*, with a funnel-shaped inlet, is fixed in each heating tube, and extends to within a few inches of its plugged-up extremity, being supported concentrically by suitable collars or projections.

The partition *C* extends upwards above the ordinary water-level in the drum, and attached to it is the sheet-iron water uptake. There are also two diaphragms in the drum, placed as shown, and the course of the water, from its entrance through the feed inlet on the left to its emergence from the uptake as steam, will be readily followed.

The circulation thus created is sufficiently rapid to carry with it the mud and calcareous salts which usually are deposited on the heating surfaces. The two currents, the descending water and the rising mixture of water and steam, being always separate, are never, in any case, able to interfere with each other No matter how much the firing may be forced, it results only in further accelerating the movement; hence the steam production is limited only by the amount of fuel which can be burnt on the grate. With forced draught by a steam jet in the chimney, the evaporation may exceed twelve pounds per square foot of

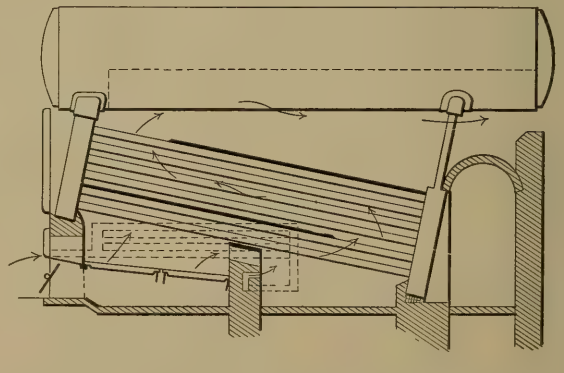


FIG. 5.—BAFFLE PLATES IN THE MATHOT BOILER

heating surface per hour without danger to the tubes.

The feed-water is injected into the steam space against a metal diaphragm, which breaks it up into small drops,

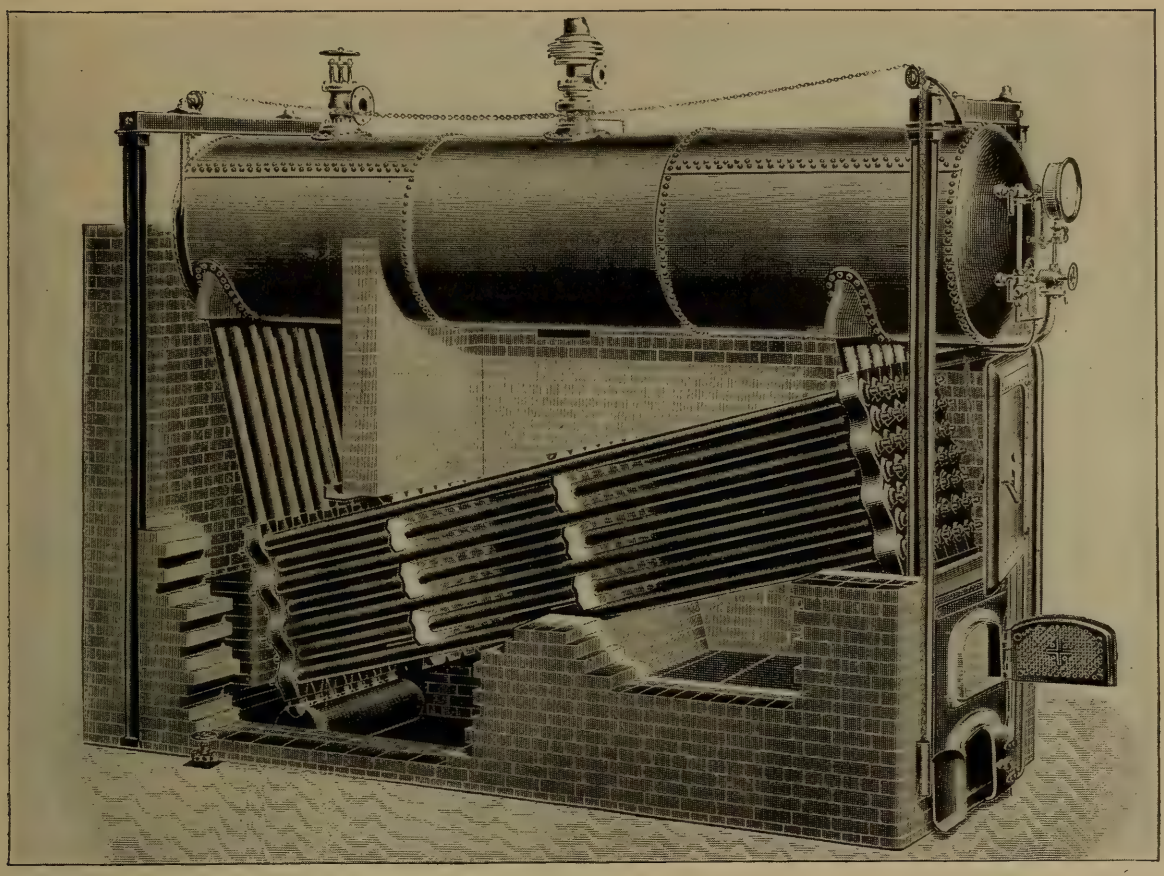


FIG. 6.—A BABCOCK & WILCOX BOILER. BUILT IN GREAT BRITAIN BY MESSRS. BABCOCK & WILCOX, LTD., RENFREW, SCOTLAND, AND IN THE UNITED STATES BY THE BABCOCK & WILCOX CO., NEW YORK

and, being instantaneously heated, it parts at once with all sediment, which is precipitated into the space *F*, whence it can be periodically blown off.

MM. Biétrix, Leflaive, Nicolet & Cie, of Saint-Étienne, supplied for the motive-power service a water-tube boiler with an evaporative capacity of 5940 pounds of water per hour, upon the Buttner system, of which they are the sole licensees. In this boiler, shown in Fig. 13, the front and rear water chambers are connected by a tube within the large cylindrical drum, open at the upper part of its circumference. This tube, as will be seen, is greatly enlarged at the end where it enters the rear chamber, and has there cut into it two large holes through which the lower stratum of water in the drum descends to join in the general circulation, with the result that over thirty-seven pounds of water may be evaporated per square foot of heating surface per hour. It will be observed that the drum itself is built into the furnace, thus forming an important addition to the amount of heating surface.

The ascending stream of water being projected with great force in a horizontal direction along the circulating tube, parts with its steam through the openings along the top of the tube in a state of great dryness. The feed-water is introduced at a point where it immediately becomes so heated as to drop its deposits, there and then, at the bottom of the drum, whence they are readily removed. Finally, thanks to the intensely rapid circulation in the tubes, they are maintained at such an even temperature as to largely avoid unequal expansion or contraction.

MM. Solignac, Grille & Cie, of Paris, contributed one 150-H. P. boiler (Fig. 14), and in the naval section also a very small, self-contained launch boiler (Fig. 15). Both these are of the type so well known as the Solignac generator. Fig. 16 illustrates the general idea of the

Solignac system, unencumbered with minor details, from which it will be seen that the boiler comprises two main parts,—the drum or water chamber *A*, and the tubular system *a a*, a_1 a_1, opening into the front header *N*. The feed-water enters the drum at *J*, in which, it is claimed, the water becomes detartarised, or purified, while awaiting the moment at which it shall pass into the tubes. It is to be understood that there is no circulation in the ordinary sense of the word, the feed-water being intended to pass only once through the tubular system, reducing ferrules being placed at the entrance of each tube to restrict the admission of water to the amount which can be vaporised at one passage through the tube. These ferrules also operate as a check or abutment, the resistance thus formed forcing the current to flow upwards, emerging as steam into the header *N*, whence it is conducted by the pipe *F* into the drum.

The advantages of this form of boiler are said to be:—Safety, owing to the small tubes; simplicity, boilers of any power being simply reduplications of a single element, every one of which is capable of producing 840 pounds of steam per hour; compactness, as these boilers, burning from 15 to 20 pounds of fuel per square foot of grate with ordinary draught, evaporate 10 pounds of steam per square foot of heating surface; low first cost, there being no delicate, costly or complicated parts; dry steam supplied, the mass of water in the drum serving merely as a store of energy, only emitting steam from its surface supplementary to that supplied by the clusters of tubes; elasticity of production. With forced draught, and under normal conditions, 22 pounds and upwards of steam may be obtained per square foot of heating surface. As to incrustation, the feed-water in the drum is heated to a temperature sufficient to precipitate its salts, where, by blowing-off, or otherwise, they can be easily got rid of.

Finally, the principle of the Solignac boiler may be applied to almost every use for which a boiler can be required, and orders can be executed in a few days by building up stock elements into he required size of generator.

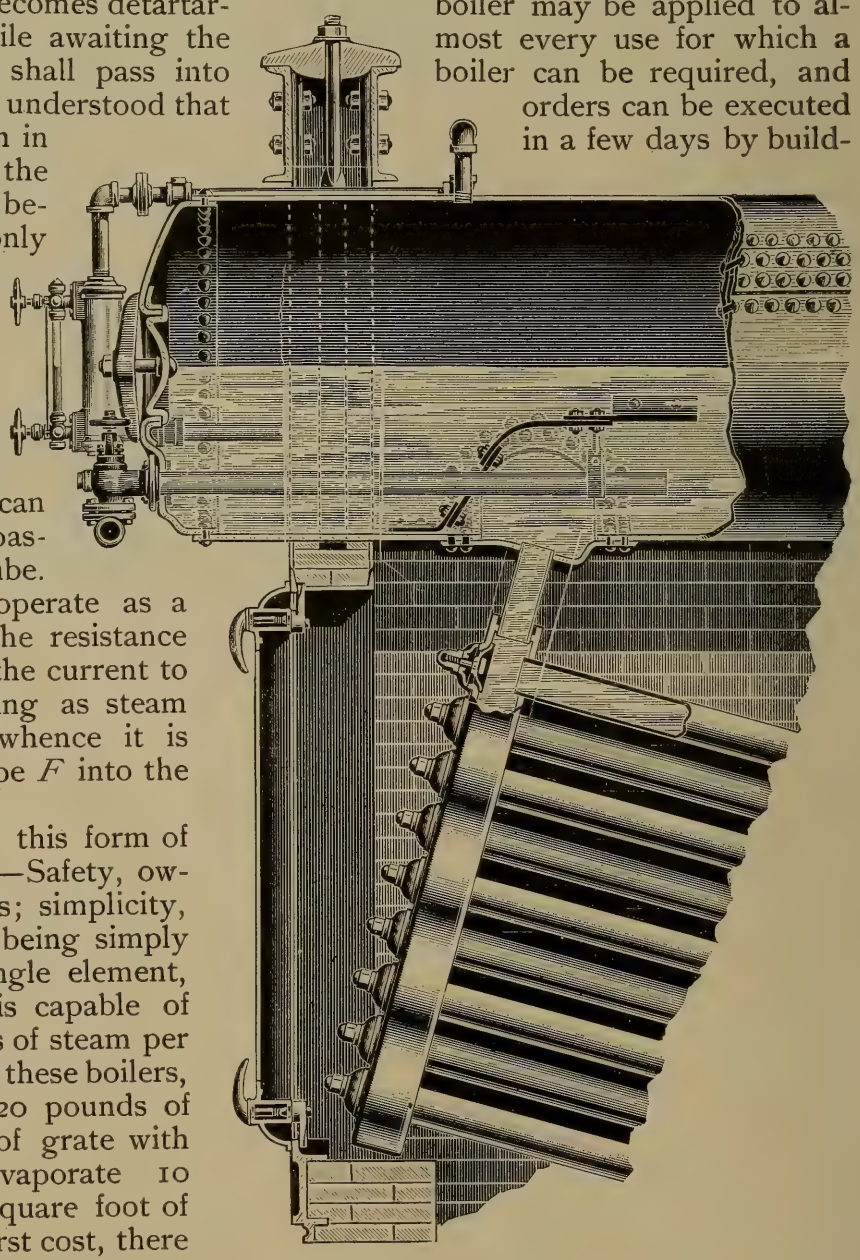


FIG. 7.—BABCOCK & WILCOX BOILER DETAILS

Messrs. De Naeyer & Co., of Willebroeck, Belgium, and Prouvy, near Valenciennes, in France, had on exhibition two large groups, comprising ten of their multitubular boilers, figuring

FIG. 8.—BABCOCK & WILCOX BOILERS EQUIPPED WITH MECHANICAL STOKERS

both as French and as Belgian manufacturers. As will be seen from Fig. 17, their boilers are composed of water tubes inclining downward towards the back end, and connected with the usual overhead drum or collector. The tubes are of wrought iron, with an outside diameter of about 4¾ inches and a thickness of $\frac{3}{16}$ inch, and ranging from 10 to 16½ feet in length, according to the size of the boiler. They are united at the ends by cast-iron or steel coupling-boxes fitted with conical iron ferrules, and made steam-tight by the screwing-up of a single bolt, without packing of any kind.

The connection of two tubes forms a section; the super-position of sections forms a series. The more sections there are in the series, the more economical the boiler. By means of vertical or parallel baffle-plates the products of combustion are divided up into five layers, with the result that 8 to 9 pounds of water can be evaporated in the simple-type boiler per pound of coal. By the use of the De Naeyer water heater, or, as we should call it, economiser, a further gain of from 10 to 15 per cent. is obtained. This feed-heater consists of a group, or groups, of tubes very similar to those of the boiler itself, but placed horizontally, preferably at the back, through which the feed-water circulates, winding in and out from top to bottom in the opposite direction to that of the heated gases.

To avoid the effects of expansion upon the containing brickwork, the clusters of tubes are suspended from the steam drum, which is itself supported by two strong girders resting upon the cast-iron base, entirely independent of the masonry. Local expansion, due to unequal heating of different tubes in a group, is provided for by the conical ferrules in the connection boxes.

Messrs. De Naeyer & Co. have adopted a rational system of feed, almost completely ridding the water of the calcareous salts it contains. By feeding directly in the current of steam which disengages itself from the steam drum the water is suddenly brought up to a temperature of from 284° to 300° Fahr., which has the effect of precipitating the salts in the form of powder, the water thus purified returning to the feed tank through an overflow pipe placed at the opposite extremity of the

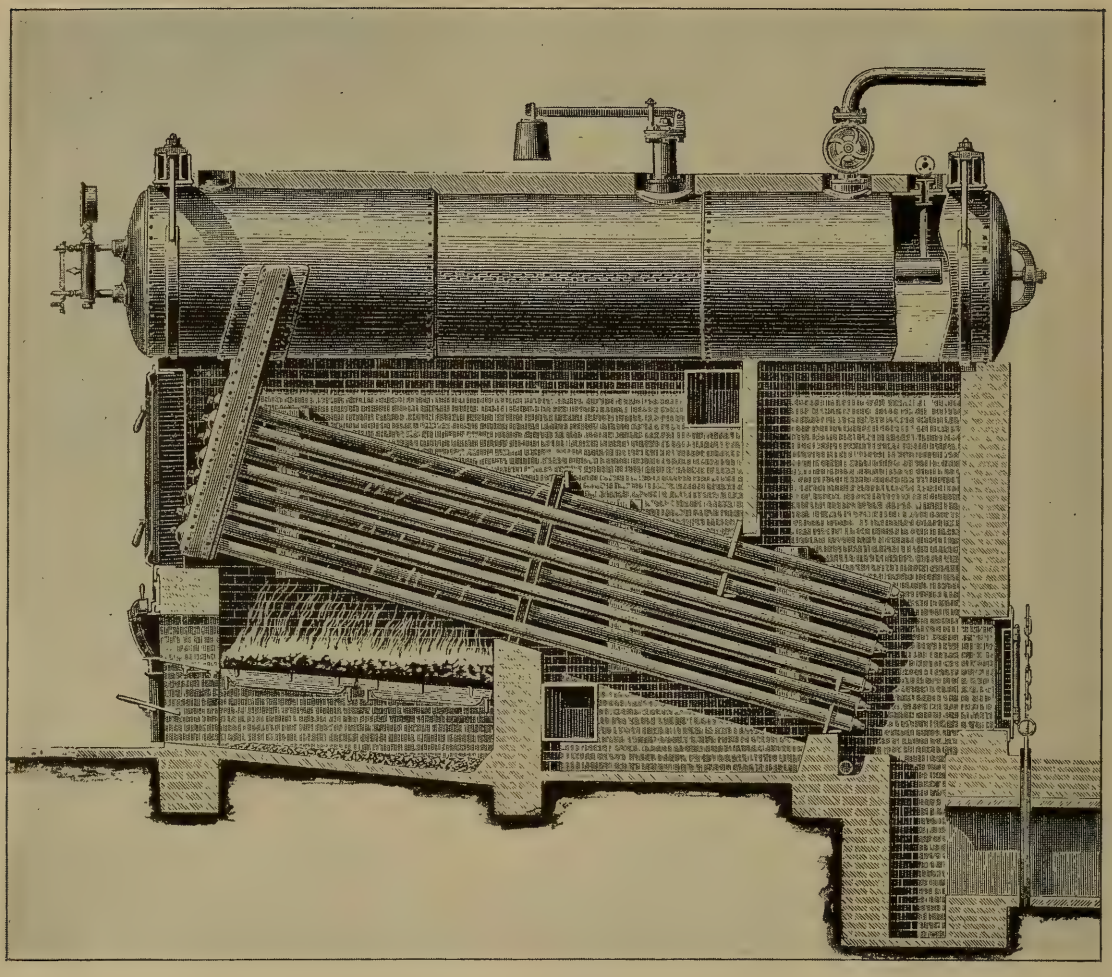


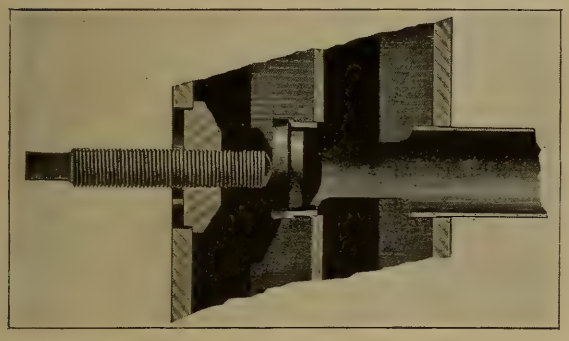
FIG. 9.—BOILER BUILT BY A. MONTUPET, PARIS

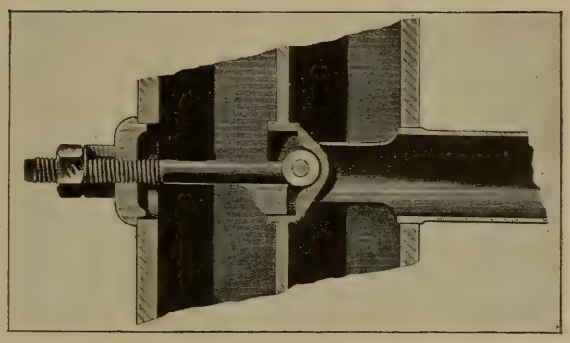
reservoir, which is a large cylinder of boiler plate fixed above the tubes, but not heated. The movement of the water in the reservoir being rather slow, the decantation is almost perfect, and the calcareous deposits reunite in the form of mud at a point where they can be easily extracted while the boiler is at work. The water, thus purified, returns into the tubular cluster.

As to dry steam, each tube is in itself a small generator, receiving feed-water at its lowest part, and discharging the steam at its highest. The large surface of the communications allows of a rapid circulation of the steam formed and a uniform distribution of the feed-water. The steam produced is received in a collector, and thence passes into the drum, which is surmounted by a dome. Interior arrangements force the steam to make a long course by changing the direction several times, always bringing it perfectly dry to the dome. The water-level is regulated so as to have always a certain quantity of water in the drum, which forms a large receiver, and is thus not affected by fluctuations in the amount of feed. With a boiler of small capacity this regularity cannot exist; the pressure will suddenly rise and fall, and the water-level will be subject to frequent variation. If the pressure falls considerably through over-feeding, the steam thus obtained will be wet steam.

The boilers, further, are constructed in such a way as to allow of their being easily taken to pieces. If a tube has to be replaced, it can be done without difficulty, and in a very short time. The process of cleaning is thus simple in the extreme. As a rule, with ordinary water, the boilers require cleaning only every six or eight weeks. Soot-doors are provided in the side walls

through which a jet of steam can be introduced, which, the makers aver, will "drive out the soot in less 'than no time'" during the working of the boiler. In the matter of ease of transport, it is worth noting that each section of two tubes can be transported separately, and everything can be carried on a mule's back. The re-erection can be done by an ordinary workman. Every boiler is tested complete, by hydrostatic pressure to 40 atmospheres.





FIGS. 11 AND 12.—TOOLS FOR INSERTING AND WITHDRAWING THE TUBES IN THE MONTUPET BOILER

Great Britain was represented in the Paris boiler exhibits by Galloways, Ltd., of Manchester, who had at work six of their well-known Galloway boilers, each 30 feet long by 8 feet in diameter, constructed for a working pressure of 160 pounds per square inch, and, together, capable of evaporating 55,000 pounds of water per hour. Photographs of the actual boilers exhibited were not obtainable, but Fig. 18 shows a group of three almost exactly similar boilers, save only that the Paris boilers were double-riveted. Each boiler contains two furnaces, joined behind the fire-bridges into a "Galloway" flue, having forty conical tubes and fourteen side pockets. The flue is constructed in accordance with the makers' 1894 patent, whereby the upper and lower plates are corrugated by a hydraulic press to a special form, in order to give great strength to the structure without unduly increasing the thickness of the plates. This arrangement also provides for the abolition of flanges for the attachment of the conical tubes, these latter being enlarged at the upper and lower ends by a special machine to the proper angle to meet the corrugations of the flue-plates, and thus the strongest connection is attained that has, so far, been introduced.

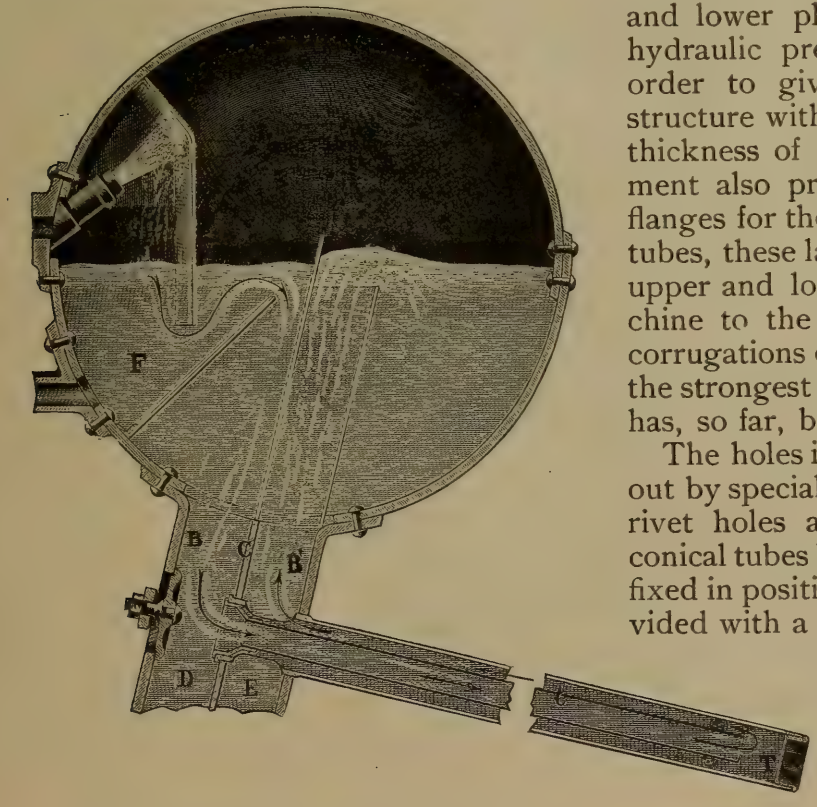


FIG. 10.—CIRCULATING DEVICE IN THE MONTUPET BOILER

The holes in the flue-plates are all cut out by special machine tools, and all the rivet holes are drilled, those for the conical tubes being drilled with the tubes fixed in position. Each boiler was provided with a full complement of fittings of Galloways' own make, and the whole of the steam, feed, and blow-off pipes across the two batteries of boilers, and connecting

them together, were provided and fixed by the makers.

Messrs. Galloways were under agreement to work these boilers for the full period of the Exhibition, and they provided fuel, attendants, and everything else incidental to their working, the Exhibition authorities simply taking the steam away as it was generated.

A peculiarly interesting exhibit, displaying the capabilities of Russian industry at the present day, was that contributed by the Société Anonyme des Establissements de Chaudronnerie et de Constructions Mécaniques, W. Fitzner & K. Gamper, of Sosnorvice,—a concern with a capital of 3,750,000 roubles, and employing over 2000 hands at day and night work. Up to date this firm has supplied 4875 steam boilers, and its sales for 1899 amounted to eight millions of roubles. As a sample of their work they offered the Lancashire boiler, shown in Fig. 19, with one of its flues laid beside it, partly cut away to better show the workmanship of the flanging and welding. The size of this boiler, which was made for 175 pounds pressure per square inch, was 30 feet 6 inches by 7 feet 7½ inches; and it will be observed that the front end plate is convex, thus dispensing with gussets or longitudinal stays. The longitudinal seams were triple-riveted with inside and outside covering strips; the circular seams were double-riveted. The flues were made in five lengths, united by Adamson joints, each length having three or more expansion rings rolled in it. The cross tubes were welded in.

Alongside this flue there was another example of welding,—a 15¾-inch steel pipe, 53 feet 6 inches long, with numerous flanged branches, forming a single

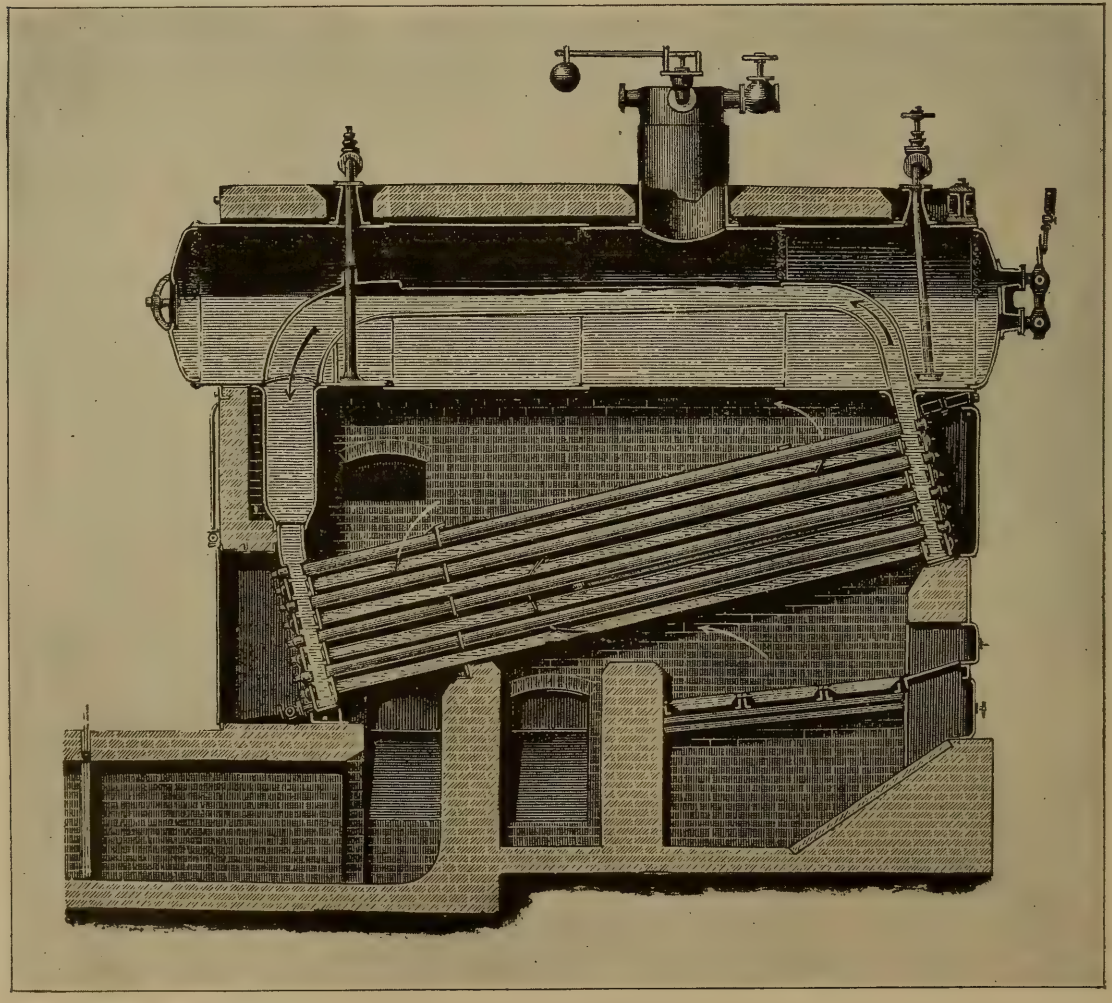


FIG. 13.—THE BUTTNER BOILER, MADE BY MM. BIÉTRIX, LEFLAIVE, NICOLET & CIE., SAINT-ÉTIENNE

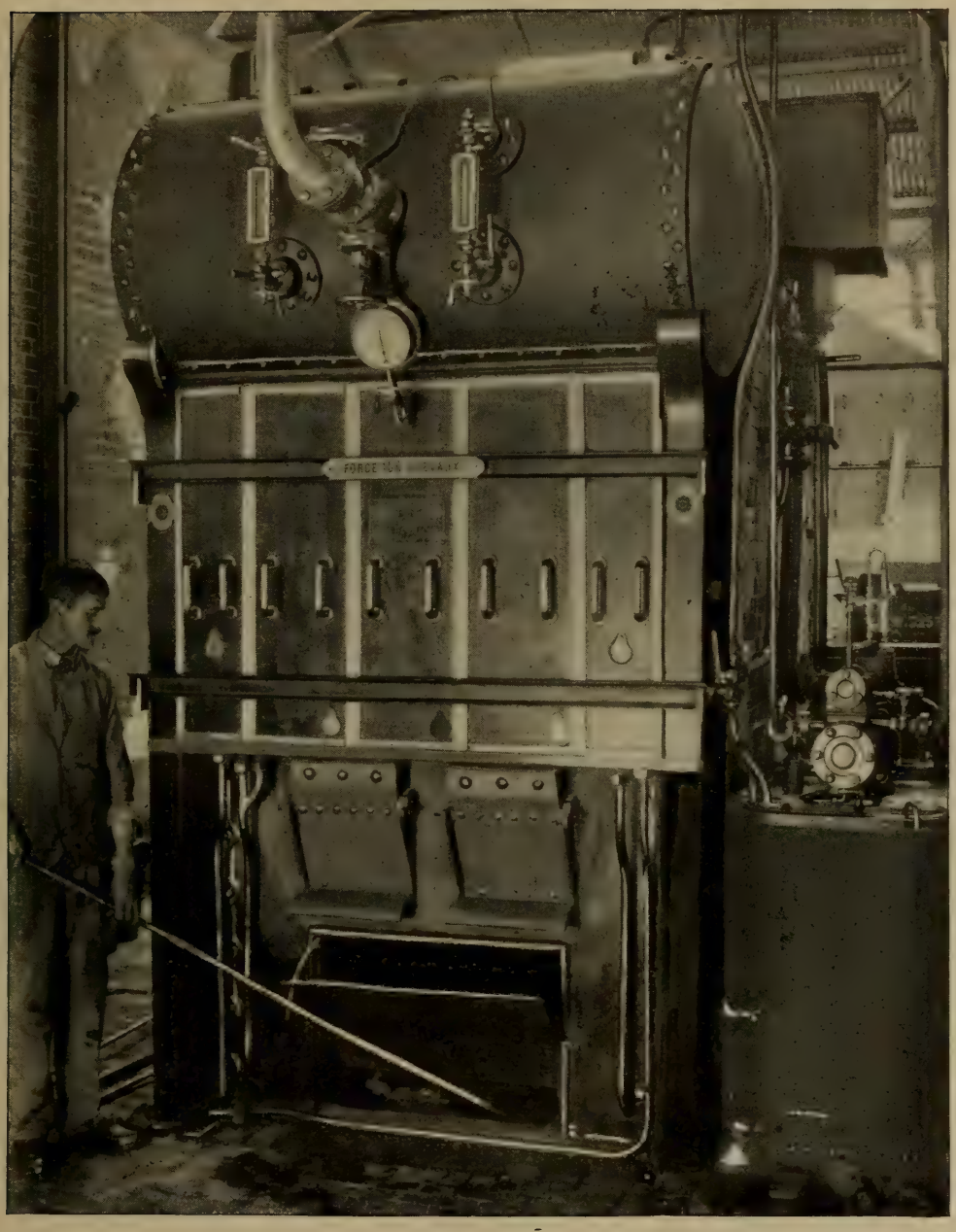


FIG. 14 —WATER-TUBE BOILER MADE BY MESSRS. SOLIGNAC, GRILLE & CIE., PARIS

piece. There was also a spherical rag boiler, without seam or visible joint, even the trunnions being welded in.

In addition to these, the same makers exhibited one of their water-tube boilers of 1300 square feet heating surface, with one side of the brickwork broken away to show the construction and workmanship (Figs. 21 and 24). They had also at work in the Suffren boiler shed a similar boiler, but with 1600 feet heating surface. The workmanship of these exhibits was uniformly excellent.

The well-known firm of L. & C. Steinmüller, of Gummersbach, Rhenish Prussia, showed the largest group of boilers in the German section. It consisted of five Steinmüller generators, each with 2740 square feet of water-heating surface, 60½ square feet grate area, and with a total evaporative capacity of 28,600 pounds of steam per hour at 132 pounds per square inch pressure.

The Steinmüller boiler, shown in Fig. 20, consists essentially of two parts,—the actual generator, and the overhead drum or receiver. The generator is composed of a system of wrought-iron

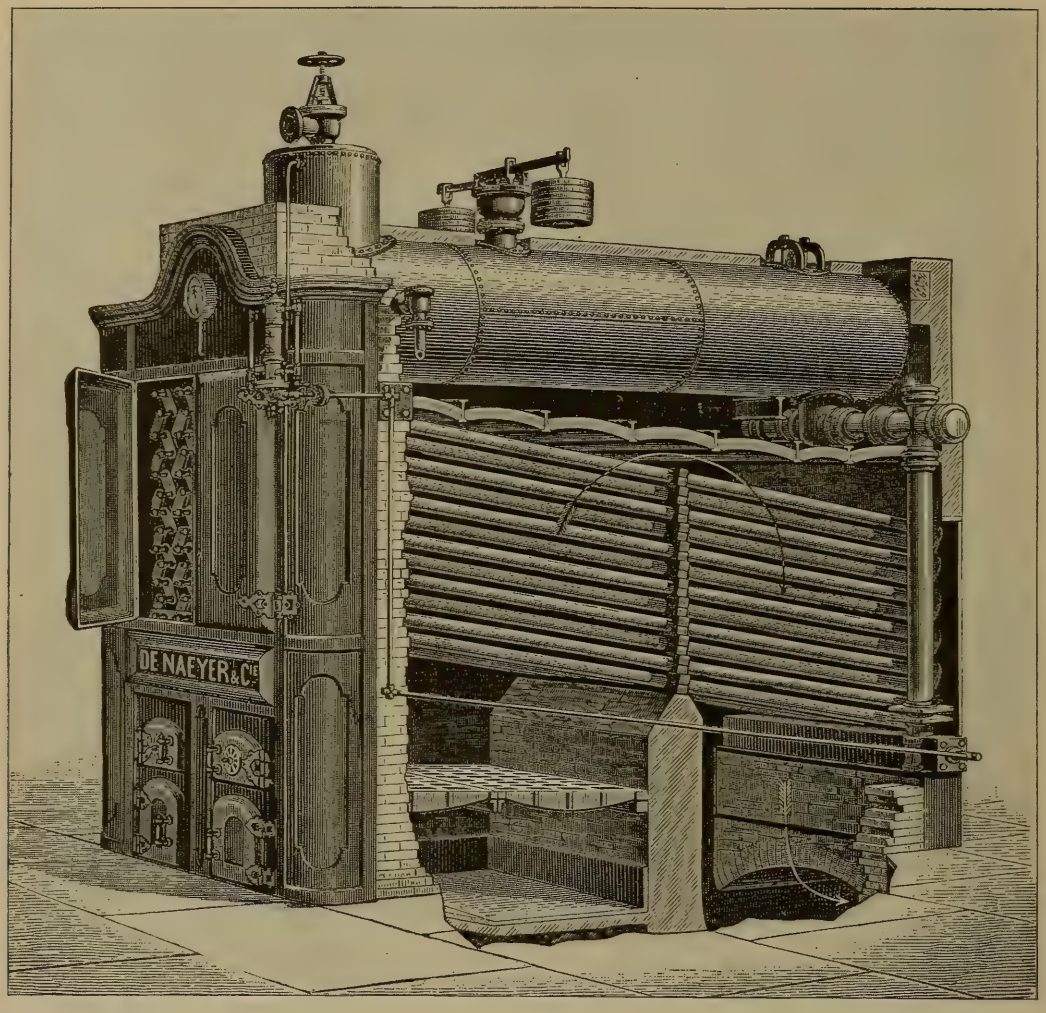


FIG. 17.—WATER-TUBE BOILER MADE BY MESSRS DE NAYER & CIE., WILLEBROECK, BELGIUM, AND PROUVY, FRANCE

tubes, expanded at both ends into vertical wrought-iron chambers or water-spaces. The drum is normally half filled with water, and the circulating arrangement consists of a casing within it, in direct communication with the front, or uptake, water-space, fitted with a horizontal tube lying along the bottom of the drum, together with a closed trough, or rectangular channel, of much larger section, extending nearly two-thirds the length of the drum, a little above the water-level.

Upon heat being applied to the tubular system, the upward current of water, entering the casing above mentioned, rushes through the horizontal tube towards the downtake or rear water-space, to be again circulated, thus heating up the stationary water contained in the drum. As soon as steam is formed, it disengages itself from the rising column of water, and, though still containing much water, rises higher in the casing, and thence flows along the trough or rectangular channel. Through a series of slots in the bottom of the latter the water rapidly falls away, leaving dry steam to emerge at the further end of the channel. A collecting pipe, running the whole length of the drum, takes off the steam at the highest point and delivers it to the stop valve, there being no dome in this instance.

The firm of Ewald Berninghaus, of Duisburg-on-Rhine, exhibited, jointly with the Elektricitäts Aktiengesellschaft, late Schuckert & Co., of Nürnberg, a group of four boilers, Fig. 25, each consisting of two shells or barrels, placed one above another, and united

only by a single neck or tube of large diameter. The lower barrel is traversed by two flues; the upper, by a large number of small tubes through which the products of combustion return to the front, thence passing over the whole external surface of both barrels. Access to the tubes is given by the cast-iron doors upon the gangway level, seen in the illustration. Each barrel has its own water-level and steam space, both steam spaces being connected by a large pipe passing through the neck. and both water-spaces in the same way by a smaller pipe alongside it, the feed being first introduced into the upper boiler.

It is claimed for this system that an evaporation of ten pounds of water per pound of coal is effected with natural draught. Two of the boilers were provided with the Morison suspension furnace, the others having the usual welded cylindrical flues, connected by Adamson flanges. Four Galloway tubes are fitted to each flue. The two plain-flued boilers are supplied with the Hering superheater, which consists of four collecting pipes fixed in the main flue, each provided with numerous small branches by which the steam is divided up into small streams exposed to the heat of the escaping gases. Each boiler had a heating surface of 2800 square feet, and the four are, together, capable of evaporating 33,000 pounds of water per hour at a pressure of 176 pounds per square inch.

FIG. 15.—SOLIGNAC LAUNCH BOILER

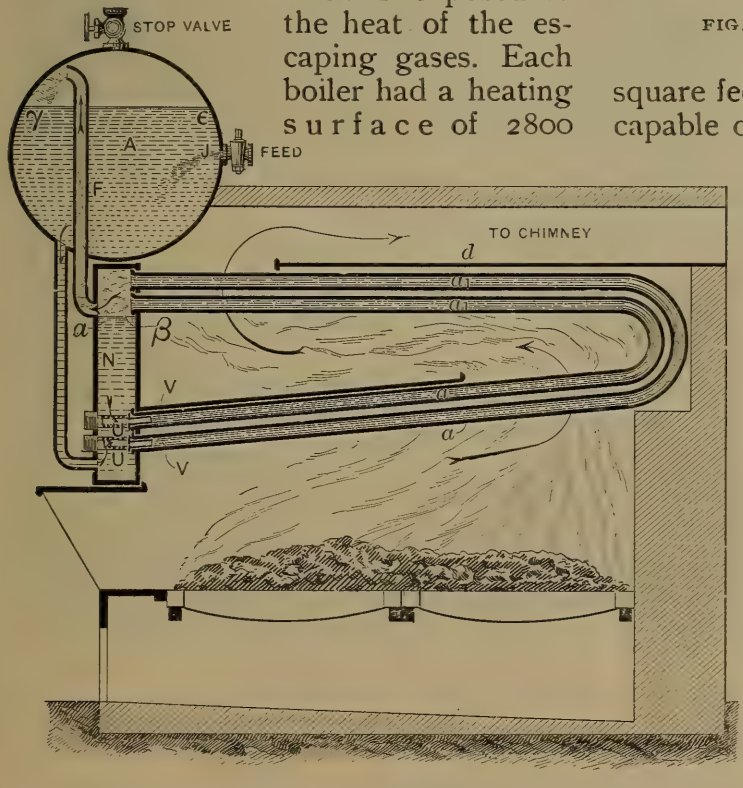


FIG. 16.—THE SOLIGNAC BOILER

In addition to the four boilers just described, the firm of Ewald Berninghaus showed, in conjunction with the Helios Elektricitäts Aktiengesellschaft, a fifth boiler of entirely different construction. This was a three-flued Lancashire boiler of rather unusual dimensions, being 36 feet long by 8 feet 3 inches diameter, with a heating surface of 1340 square feet, and a total grate area of 48 square feet. This large boiler was intended for a pressure of 176 pounds

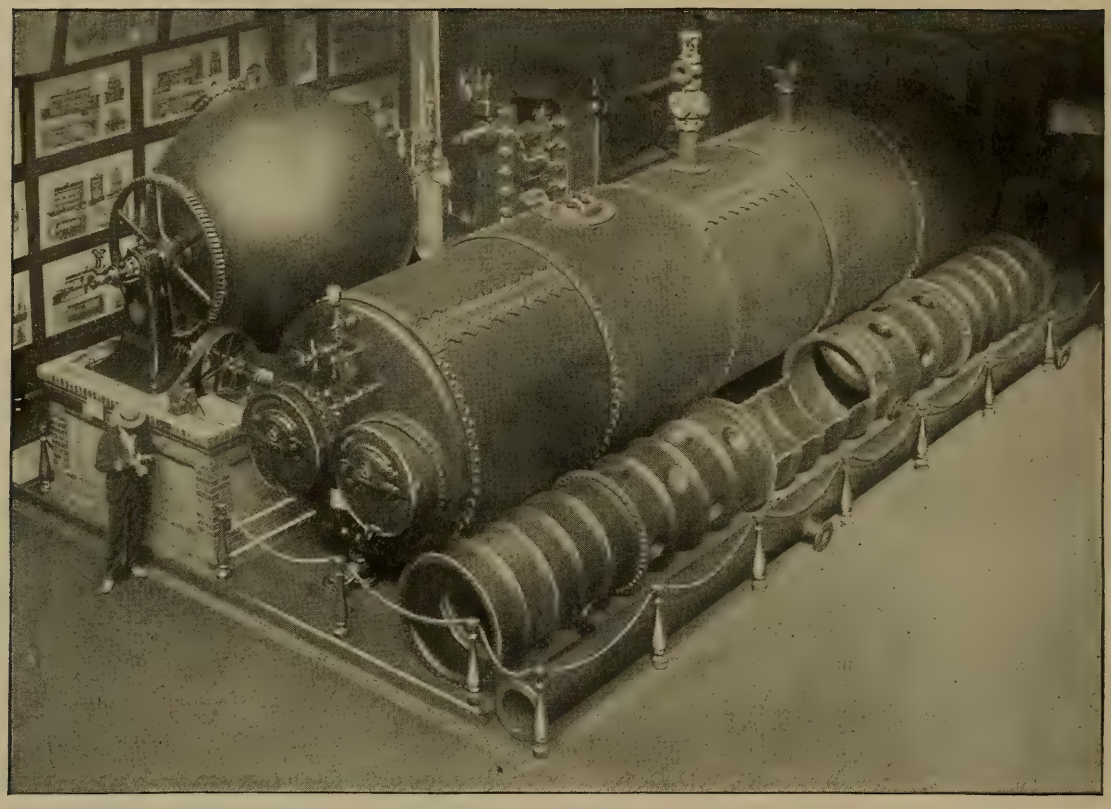


FIG. 19.—THE EXHIBIT OF THE W. FITZNER & K. GAMPER CO., SOSNORVICE, RUSSIA

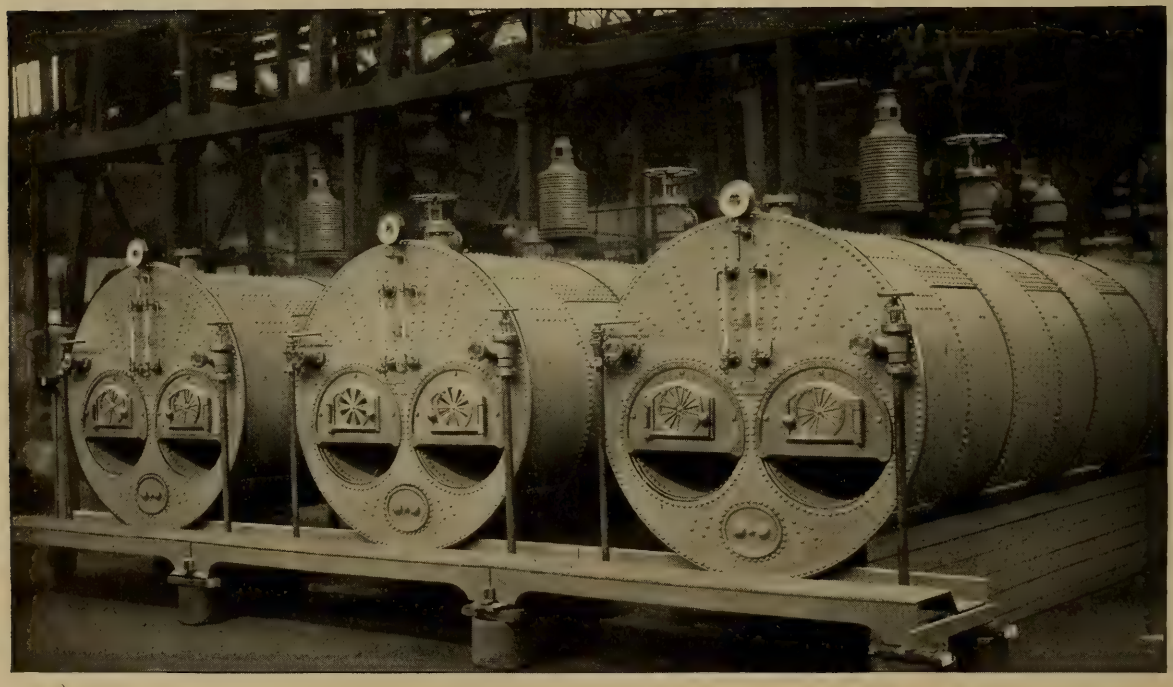


FIG. 18.—BOILERS EXHIBITED BY MESSRS. GALLOWAYS LTD., MANCHESTER, ENGLAND

per square inch, but, in common with others, it was worked during the period of the Exhibition at only 147 pounds. The flues were welded, cylindrical tubes, united by Adamson rings. The ends of the boiler were convex, and no gussets or longitudinal stays were employed. Two feed-heaters, or economisers, were placed in the brickwork flues.

Co., of Landsberg, exhibited, in connection with the Helios Company, a peculiar type of boiler, or rather, pair of boilers, with their system of graduated flues, having a total heating surface of 1076 square feet (Figs. 22 and 23), adapted for a working pressure of 176 pounds per square inch.

As will be seen, the flues are fixed

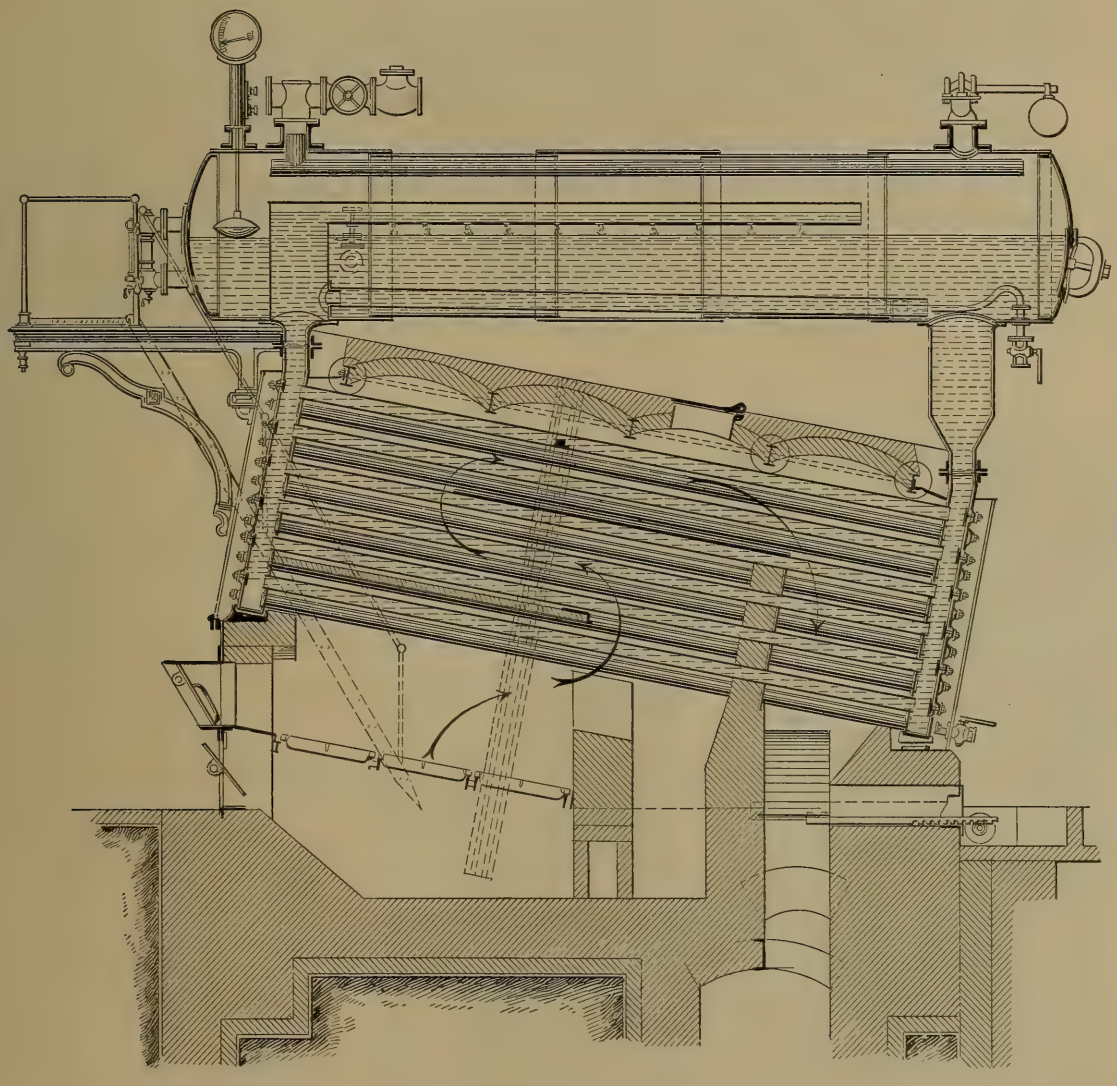


FIG. 20.—THE WATER-TUBE BOILER OF MESSRS. L. & C. STEINMULLER, GUMMERSBACH, GERMANY

To each of the Berninghaus boilers was fitted a Siemens-Halske "carbonic-analysator,"—an apparatus which automatically registers, by means of photography, the more or less complete combustion of the fuel, thus keeping a watch upon the stoker, which cannot fail to be of value to the employer.

The German firm of H. Paucksch &

eccentrically in the shells, the latter being placed almost in contact with one another. The products of combustion first traverse the boilers by the two internal fire-tubes, and, uniting at the back, pass forward between and under the boilers; thence, separating to right and left, they once more pass along in contact with the outer part of the shells, to finally emerge at the chimney.

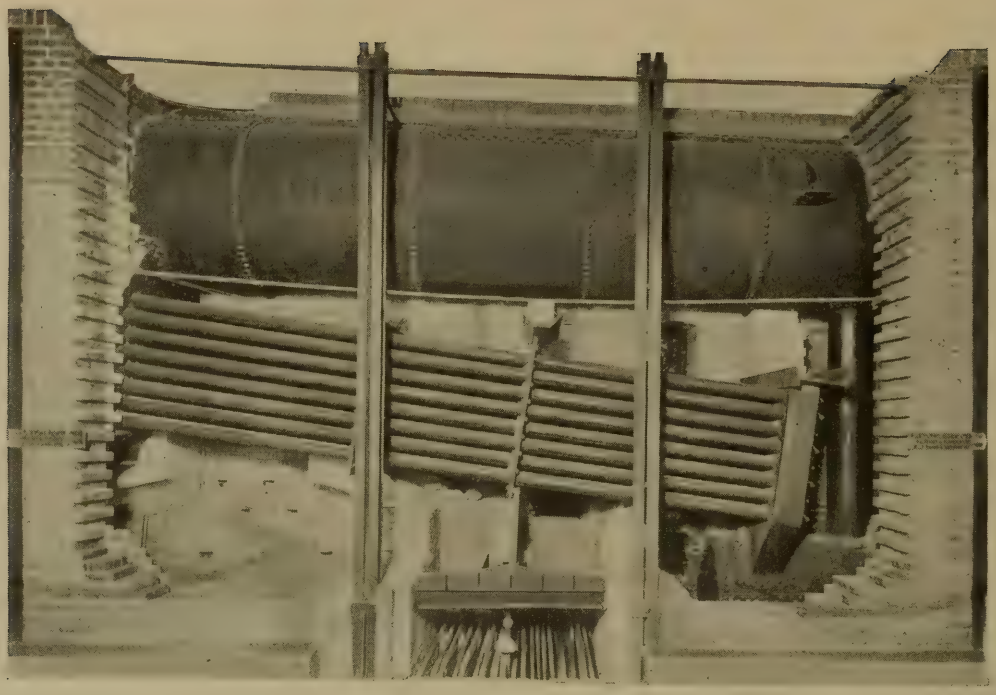


FIG. 21.—WATER-TUBE BOILER MADE BY THE W. FITZNER & K. GAMPER CO., SOSNORVICE, RUSSIA.

This method was patented by D. R. Paucksch about seventeen years ago, and has since been the specialty of this firm, over 1600 boilers having been built by them upon this principle. The singular form of the flue (which consists, firstly, of five rings of plate 900 mm. diameter, then one ring of 800 mm., followed by alternate rings of 750 mm. and 700 mm. to the end of the flue) appears to have been adopted for the purpose of giving longitudinal elasticity, combined with great strength against collapsing pressure. As the lower edge of the flue, as seen in Fig. 22, presents a straight line, the flanges uniting the alternately larger and smaller rings are eccentric to the axis, or sickle-shaped, —a form of construction in which their alleged capability of breaking up and mixing the heated gases would seem to be dearly purchased at the cost of the additional complication involved.

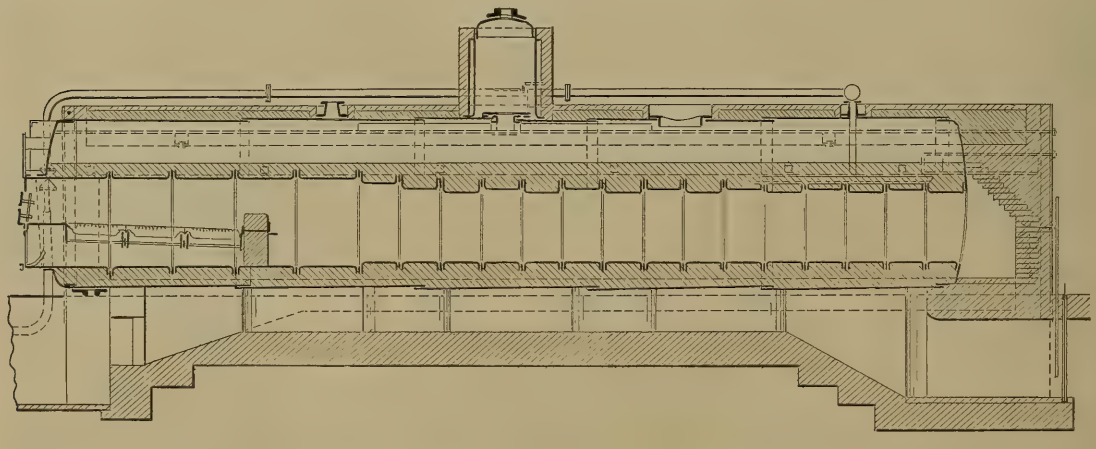


FIG. 22.—BOILER WITH GRADUATED FLUES, MADE BY MESSRS. H. PAUCKSCH & CO., LANDSBERG, GERMANY

The shells are 5 feet 7 inches in diameter by 30 feet 6 inches long, and, as they give the same heating surface that a Lancashire boiler of double the diameter with similar flues would have,

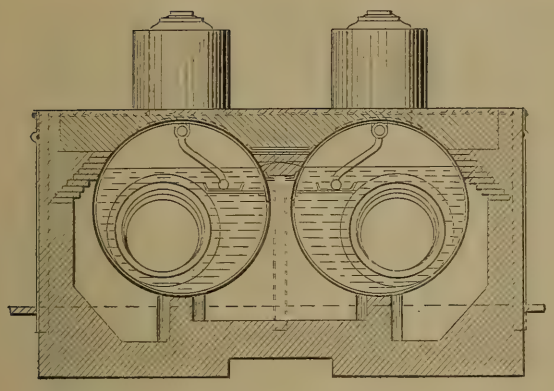


FIG. 23.—CROSS SECTION OF THE PAUCKSCH BOILER

this system of twin Cornish boilers presents considerable advantages in the way of transport, the two units together being only one-half the weight of the equivalent Lancashire boiler.

The boiler of Messrs. Simonis & Lazn, of Frankfort, which they exhibited jointly with the Helios Company, is described as a "Circulation Boiler," on the two-chambered system, which, being interpreted, means a water-tube boiler in which the inclined heating tubes are fixed at both ends into narrow water-spaces, or chambers, depending from the cylindrical drum overhead. In the boiler under notice there were 128 of these tubes, nearly 17 feet in length, of wrought iron, welded, and expanded into the front and rear tube-plates. The overhead drum or receiver, which was surmounted by a vertical steam dome, was 4 feet 3 inches in diameter by 21 feet 6 inches long, and was designed for a working pressure of 176 pounds per square inch.

The water-heating surface was 2280 square feet, of which 2140 feet were tube-surface. The grate area was 57.35 square feet. In ordinary use, burning 16 pounds of coal per foot of grate per hour, this boiler is capable of evaporating 8360 pounds of water per hour into steam at 176 pounds pressure, or about 9 pounds of water per pound of fuel.

A circulation accelerator, consisting of a number of waved or corrugated plates, is fixed within the overhead drum, over the uptake of the front water-chamber, by which the ascending stream is split up and distributed, "thus promoting the circulation, increasing the life of the boiler, and producing drier steam."

Messrs. Petzold & Co., of Berlin, also joined in supplying steam for the Helios Company's group of engines. Their boiler consisted of two parts,—the "under boiler," a double-flued cylindrical vessel, fitted with corrugated flues, and the "upper boiler," tubu-

FIG. 24.—BOILER MADE BY THE W. FITZNER & K. GAMPER CO.

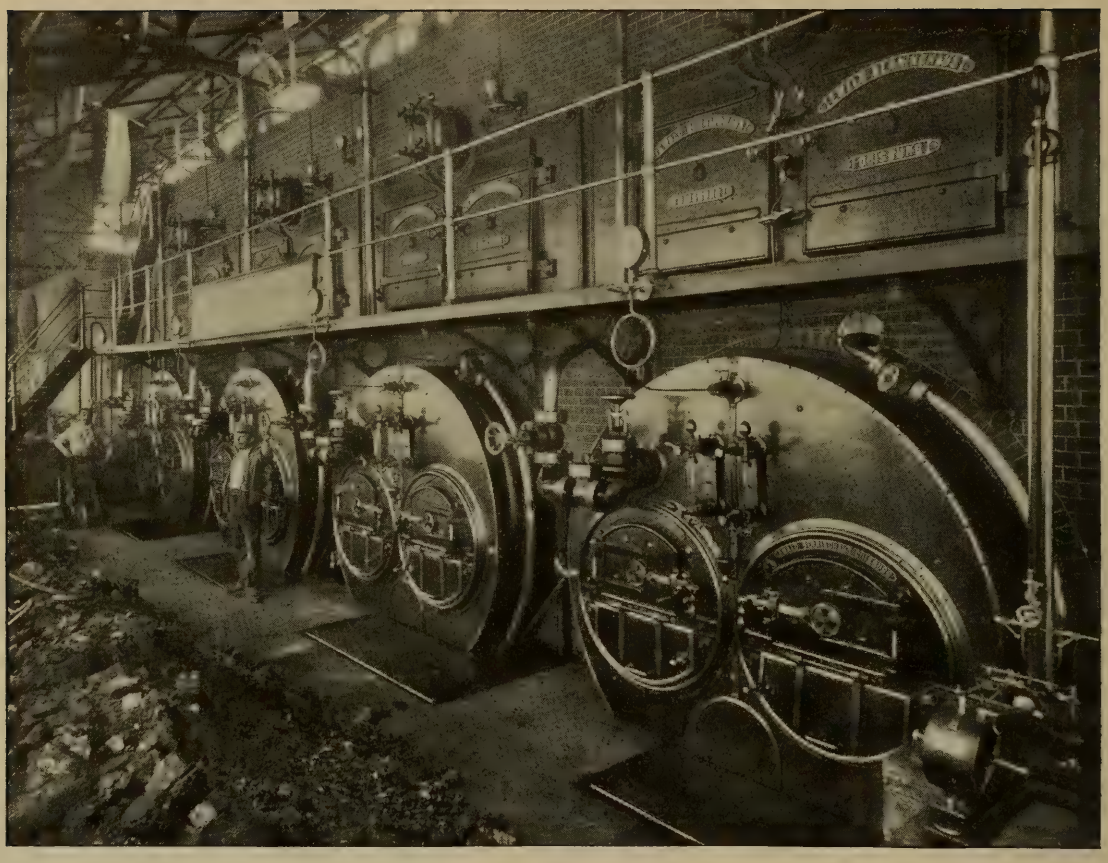


FIG. 25.—THREE FLUED LANCASHIRE BOILERS MADE BY EWALD BERNINGHAUS, DUISBURG, GERMANY

lar, with seventy-eight Mannesmann tubes. The feed-water was first introduced into the upper boiler, and thence, by an overflow pipe, heated by the steam throughout its length, into the lower boiler. The cleansing of the interior of the entire boiler is well provided for by a system of doors and hand-holes. The total heating surface amounted to nearly 2750 square feet, the grate area being only 39 square feet.

The last of the boilers in connection with the Helios Company was that contributed by MM. Petry - Dereux, of Düren, Germany. Described as a water-chamber boiler, it had no less than 3185 square feet of heating surface, with a grate area of 64 square feet. The main peculiarity of the Petry-Deveux system consists in the arrangement that a water partition conveys the feed-water, in the first instance, to the lowest line of tubes, so that the fullest flow and greatest cooling occur in those tubes which are immediately exposed to the fire. "By this means the durability of the tubes is better ensured than by other systems where the circulating water takes the shortest way through the upper rows of tubes, allowing the lower rows to become overheated."

The arrangement of the water-partition in no way obstructs the access to the tubes, as a hand-hole is provided in front of each tube, secured by a simple cover. The chambers are welded, the front chamber being directly riveted to the overhead drum. At the rear end the chamber is removable by means of a faced and bolted joint whose flanges are riveted to the drum and to the chamber, respectively.

Neither the ordinary marine boiler nor the locomotive type was represented at all. In this vast collection of steam generators almost every specimen contained some originala features, and it has been the writer's endeavour to give prominence to the peculiarities observed in some of the less known types, in the hope that this display of Continental ingenuity may not be without its lessons for those of us who are interested in the making and using of steam boilers.

LIQUID FUEL

SOME CONCLUSIONS FROM RECENT TRIALS

By E. L. Orde

THE early history of liquid fuel has been so ably presented in various published papers that it seems unnecessary to recapitulate what has been done up to the present time with this form of combustible. Renewed interest is, however, attached to the practical results of some experiments carried out by Mr. Orde and to the conclusions to which they have led. These formed the basis of a paper recently presented by him to the North-East Coast Institution of Engineers and Shipbuilders, and reprinted in the following pages.—THE EDITOR.

It is only within the last few years that liquid fuel has come within the province of engineers in this country, owing to the fact that hitherto it has been practically obtainable only in the vicinity of the Caspian Sea at such a price as renders it commercially possible. New oil fields have been discovered, and the number of places along the Eastern route at which liquid fuel can be obtained has increased so enormously that it becomes a serious question for shipowners to consider whether it is not an absolute economy to use it in preference to coal on vessels trading to the eastward. The solution of this question lies, first, in the cost of the fuel and its practical calorific value as compared with coal. Secondly, in its effect on the life of the boiler furnaces in which it is burnt; and thirdly, perhaps the most important of all, its immunity from danger. The first point is, of course, constantly varying, and is one which the writer is not in a position to pursue. The two latter practically resolve themselves into one,—the efficient combustion of the fuel. The existing appliances designed for the purpose may be broadly divided into three kinds:—

1st. Those in which the liquid fuel is injected into the furnace in the form of a spray by purely mechanical means.

2d. Those in which the spray is produced by the introduction of a gaseous medium.

And 3d. Where the liquid fuel is introduced into the furnace in the form of vapour.

Before considering the respective merits of these three classes of apparatus, it will be advantageous to realise the actual possibilities of the fuel. The experiments which the writer carried out were made with crude Borneo oil, which is in all respects an excellent fuel oil, and is to be obtained in large quantities. Its composition is:—

Carbon	87. 9 per cent.
Hydrogen	10.78 " "
Oxygen	1.24 " "

The flash point is 211° F.; the boiling point is 395° F. The calorific value is 18,831 B. T. U. It is an exceptionally clean and mobile fuel oil, and, with its high flash point, the risk of explosion is reduced to a minimum.

All fuel oils are exceedingly complex, inasmuch as they are made up of a number of combinations of carbon and hydrogen, which only a chemist who has devoted himself to investigating hydrocarbons can appreciate at their true significance. The importance of this point for the practical purposes of the engineer lies in the fact that the various constituents of the fuel give off vapour at temperatures varying from about 100° F., up to the boiling point of the oil, and when the boiling point is approached,—unless special precautions are taken,—a residue of solid carbon is

formed which will soon choke any pipes or narrow passages through which the fuel may have to pass. Having thus considered the characteristics of a typical fuel oil, we may now return to the consideration of the apparatus for burning it.

In the first type, the purely mechanical spray, the oil is discharged under pressure into what is commonly called a burner, which is made of such a form that the effluent jet is broken up into particles sufficiently small to burn readily at the firing point of the fuel. The full efficiency of the system can be obtained only by lining the furnace with fire-bricks, or other non-conducting material, so as to raise the furnace temperature (by preventing the absorption of heat into the boiler) until it is sufficiently high to vapourise the greater portion of the oil before it is burned. The quantity of air required to complete combustion is very largely in excess of what is chemically necessary, and the furnace space required for oxidation is large. The advantages of the system are its simplicity and its noiselessness. As regards efficiency, the best results that the writer has been able to find recorded show an evaporative efficiency of about 12.5 pounds of water from and at 212° per pound of oil. With Borneo oil this gives a fuel efficiency of 64.6 per cent.

In the second class, the oil is introduced into the furnace in the form of a spray in the presence of a gaseous medium,—be it steam or air. In most of these appliances a partial lining of fire-brick is fitted in the furnace, and brick bridges, or baffles, of various forms are built with a view of obtaining complete oxidation of the fuel. The earliest form of this apparatus consisted simply of two pipes, lying one above the other, with their ends flattened so as to spread the streams of oil and steam. Oil is admitted to the upper pipe and is allowed to drop from the orifice into the jet of steam which passes through the lower pipe, and, meeting the oil, breaks it up into particles sufficiently small to ignite as soon as the firing point is reached.

This simple device has been improved upon by numbers of engineers, and most of the improved burners of this type take the form of concentric tubes, through which the oil and steam are passed. Adjusting arrangements are always provided, so that the supply of the two elements can be regulated at will. This type is better known than any other, and has, so far, given the best results. The evaporative efficiency of the best burners of this type seems to be about thirteen to fourteen pounds from and at 212°, but the supply of air required for combustion, though smaller than that demanded by the first class of burner, is much above what is chemically necessary. The difference between steam and air as spraying media will be touched upon hereafter. The third class of apparatus, that is, in which the fuel oil is wholly or partially vapourised, promises to give the best results.

Attempts were made so long ago as the year 1867 to produce an apparatus on this system, and Colonel Foote claimed remarkable results for his method of solving the problem; these results, however, seem not to be well authenticated. Later, Messrs. Dorsett and Blyth attempted to boil the fuel in one boiler and burn the resultant vapour in the furnace of another. This, however, does not seem to have been very successful. Mr. Thwaite has since then made an apparatus consisting of a retort which is maintained at a red heat, and into this a spray of steam and oil is blown; the oil is immediately volatilised and passes through holes in the retort into the furnace, where it is met by a stream of air in which the vapour burns with a clear, blue flame. The results are said to be satisfactory, but it is difficult to see how such a process can be carried out with ordinary fuel oils without producing a large deposit of carbon in some form in the retort.

An experiment tried by the writer with an apparatus on this principle showed that it was possible to produce a high furnace temperature and a smokeless fire, but the retort was soon completely choked with solid carbon, or, if the temperature was allowed to fall, with

a pitch-like substance. This deposit presents the greatest difficulty in the way of completely vapourising so complex a body as the ordinary fuel oil. As has been pointed out before, the oil consists of a number of hydrocarbon combinations, each of which has a different boiling point.

Another important characteristic of these hydrocarbon compounds is that, in the presence of superheated steam, they can be completely distilled without crocking, and the explanation of this fact (on which depends the Ragosine process for refining petroleum) has been stated to be that in the presence of superheated steam, the boiling point, or more correctly, the mean boiling point, of the oil is lowered. This distillation, however, does not apparently take place with any other medium but steam.

To ensure distillation it is necessary that the temperature of the oil be raised to as near the boiling point as possible before it is admitted into the presence of the steam, and it is in this part of the process that the danger of crocking appears. In the apparatus fitted by the firm with which the writer is connected the difficulty has been overcome, and so far as it has been possible to ascertain by ordinary means, complete vapourisation has been secured. The vapour thus produced can be completely oxidised by the amount of air chemically necessary, and a larger quantity of oil can, therefore, be treated in the same furnace space than by either of the two other systems, while the combustion, as shown by the analysis of the waste gases, is complete. Two typical analyses are given below:—

ANALYSIS OF WASTE GASES.

Carbon dioxide	=	13.2 per cent
Oxygen	=	3.6 " "
Carbon monoxide	=	0.0 " "
Hydrocarbon gases	=	0.0 " "
Hydrogen	=	0.0 " "
Nitrogen	=	83.2 " "
		100.0 per cent.

Carbon dioxide	=	12.6 per cent.
Oxygen	=	4.0 " "
Carbon monoxide	=	0.0 " "
Olefines, etc.	=	0.0 " "
Hydrogen	=	0.0 " "
Nitrogen	=	83.4 " "
		100.0 per cent.

The only feature calling for remark is the somewhat large percentage of uncombined oxygen, which is no doubt due to leakage around the smokebox. As regards efficiency, an evaporation of from fifteen to sixteen pounds from and at 212° should always be obtained with dry Borneo oil.

The hyydrocarbon vapour is exceedingly unstable, and appears to depend for its existence entirely on temperature. Efforts have been made to collect samples for analysis, but without success. In appearance it is of almost milky whiteness, closely resembling the vapour given off from the retort used in the Pintsch gas system. The smell is pungent, and severe irritation is set up in the membranes of the mouth and throat if the vapour is inhaled.

At the temperature of the external air (60°) it was found almost impossible to ignite it, and the outer surface of the jet was at once condensed and formed an oil deposit of a very much lighter colour than the fuel oil itself. The flame, when the vapour is burned in a boiler furnace over a layer of broken fire-brick, is of dazzling whiteness, and becomes almost transparent as it approaches the bridge. The exact form in which the combustion of these hydrocarbon vapours takes place does not seem to be clearly understood. The appearance of the flame at a distance of a few inches from the nozzle of the burner suggests that at that point the hydrocarbons are burning in the form of acetylene.

All gaseous hydrocarbons, when exposed to a temperature of 1000° F., become acetylene, and it seems fair to assume that the vapour will do the same. As the flame proceeds further into the furnace, however, and the temperature becomes higher, the hydrocarbon combination must break up, and the rest of the vapour is probably burned as carbon monoxide and hydrogen. There seems to be no doubt that the efficiency of liquid fuel lies in the fact that it is capable of being turned into vapours of high calorific power, and that the vapourising process does not demand a large heat expenditure.

The two classes of apparatus first described do not vaporise the fuel before combustion begins, which means that of the heat generated in the furnace some considerable part is absorbed for this purpose, and is, therefore, not available for evaporating water. To attain to the temperatures required for complete vaporisation, part, at all events, of the constituents must be exposed to the heat of the furnace, but with careful design the quantity of heat thus abstracted can be reduced considerably below that which is necessary to carry out the process when the fuel is simply injected into the furnace as spray. The fact that superheated steam lowers the boiling point of hydrocarbon oils, and, therefore, prevents cracking, renders its employment essential if it is desired to burn the fuel as vapour. The objection to using it on board ship is, of course, the loss of fresh water and the amount of heat loss in making this loss good by distilling sea-water. This loss, however, is,—the writer ventures to think,—more than compensated by the gain in efficiency due to using steam as a distilling agent. Mr. Morison has published some calculations of the quantity of fuel required for distilling purposes, and applying these calculations to a steamer with engines indicating 2000 H. P. at sea, the quantity of oil fuel required to make up in the evaporator the water lost in the burners amounts to only one-quarter of a ton per day of twenty-four hours. In this calculation Mr. Morison's calculated result has been multiplied by four to allow for deposit on the surface of the evaporating coils.

With air as a spraying agent, there is, of course, no loss of fresh water, but it is questionable whether the quantity of steam used in the air compressors is not greater than that required in the burners and evaporators together. The complete combustion of petroleum spray depends, firstly, on the correct relation between the volumes of the oil and the spraying agent, and secondly, on the velocity of the spraying agent, both of which requirements place air at a considerable disadvantage as compared with the steam. The general conclusions produced from the investigations the writer has made are as follows:—

(1.) Liquid fuel of good quality, such, for instance, as Borneo oil, used in boiler furnaces, if efficiently treated, should show a reduction in consumption of about 40 per cent., as compared with coal.

(2.) A reduction in bunker space of about 15 per cent for the same weight of fuel; a reduction of about 50 per cent. for the same radius of action

(3.) A reduction in the stokehold staff of at least 50 per cent.

The advantages of liquid fuel as regards ease of manipulation, cleanliness, absence of smoke, reduced temperature of stokehold, as compared with coal, increased life of boilers owing to constant temperature, improved performance of engines owing to constant steam pressure, need not be enlarged upon, but the question of immunity from danger requires some consideration. With a fuel oil of which the flash point is 200° F. or over, there should be no risk of explosion whatever, and unless there is want of ordinary care in the management of the burning apparatus and the fuel supply, the danger of fire ought not to exist. Still, fires have occurred, and it may be well to consider the causes from which they have originated.

The most fruitful cause appears to be intermittent action of the burning apparatus. This may arise from dirt in the oil or from the presence of water. To get rid of the dirt it is only necessary to provide an efficient filtering apparatus, and this should form a part of all liquid fuel installations. The second cause, the presence of water, presents a more difficult problem. All crude oils have a certain proportion of water intimately mixed with them, and, as the specific gravity of most fuel oils is from 0.9 to 0.98, and in the case of some shale oils even higher, it is obviously exceedingly difficult to eliminate this water by gravitation unless the temperature of the mixture is comparatively high. The expansion of oil under increase of temperature is considerably

greater than that of water, and some arrangement whereby heat can be applied to the contents of the bunker seems to be necessary where crude oil is used.

In furnaces where the oil fuel is burned in the form of vapour the danger of extinction from the fact that water is present is, of course, considerably reduced, for any temperature that is sufficiently high to vapourise a fuel is more than sufficiently high to evaporate water, so that when water passes into the apparatus with the oil it flashes into steam, and though it breaks up the stream of hydrocarbon vapour, it does not prevent each fraction from burning, unless the amount of water is abnormally large.

An experiment made by the writer showed that the fire was not extinguished when water was present in the proportion of five parts of water to three of oil. The water in this case was added gradually, and the contents of the bunker were constantly stirred so as to secure as complete an admixture of the oil and water as possible.

With a burning apparatus of the second type, where the oil fuel is introduced in the form of spray, the danger of extinguishing the fire when water is present is much greater, but with a well-designed installation and proper care on the part of the attendants, such accidents as fires should be impossible.

THE INDUSTRIAL PROBLEM OF GREAT BRITAIN

THE NEED OF COLONIAL DEVELOPMENT. A CANADIAN OPINION

By William T. Allison, M. A.

AT this time, when Great Britain is recognising the gravity of the industrial situation, and is waking up to the fact that her trade is slowly being taken from her, everyone is busy propounding improvements in methods of doing business, advising up-to-dateness in processes of manufacture, and insisting upon energy, always more energy.

These suggestions are all commendable, but is the question of resources not vital in discussing this threatened commercial crisis? The tremendous growth of American industry, notably in the iron and steel trades, has been quite as much a matter of stupendous resources as of improved methods and the employment of capital on an immense scale. In the United States the manufacturer does not have to depend on foreign supply for his raw material; and the producer of the raw material is rapidly becoming a manufacturer as well, or, at any rate, disposes of his produce to a manufacturer near at hand, while formerly he shipped to the British market. The recent rise of cotton manufacturing in the southern states of America is a strong illustration of this new tendency, demonstrating the helplessness of the textile industries of Great Britain which depend upon foreign supplies for their raw material. The resources of Great Britain, then, are sadly limited. But the resources of her colonies are her future strength. In the resources of Canada alone the British Empire possesses a guarantee of a continuance of commercial greatness.

In all discussions on the present crisis the importance of the colonies as a basis of supplies and as future fields of vast industries has hardly been touched upon. It is the duty of a Canadian writer to call attention to the inestimable natural riches of the great Canadian Dominion. One reason why the Canadians have been so enthusiastic in favour of imperial federation is because they realise that the hope of the Empire lies in the development of the colonies. It

is to be regretted that the people of Great Britain and her public men have failed to awaken to the fact that a country as large, and in many respects as full of resources, as the United States is theirs to develop. If the Briton is densely ignorant respecting the resources of Canada and other of the colonies, the American is not; he is casting covetous eyes upon the vast country to the north of him, and already some of the most important industrial enterprises in the development of the natural wealth of Canada are due to Yankee "push" and alertness. It is most humiliating to every Canadian that their country is being exploited by American capitalists while British money lies idle at home or is being sent to the United States to build up the power of the commercial enemy. There is plenty of room in Canada for all efforts that can be put into operation by British capital during the present century, and the resources are simply illimitable.

Andrew Carnegie has been drawing a forecast of the iron and steel trade of the new century. He prophesies that the great works of America will be centred on the southern shores of the Great Lakes. He speaks in the most sanguine tones of this quarter being the future seat and centre of the steel industry. The splendid waterway and natural advantages are pointed out by him, and the brilliant future of the lake cities is pictured by his graphic pen. But the iron and steel possibilities of Canada, and more especially of the province of Ontario, should be properly appreciated by British capitalists. There is the same chance of building up great cities in Canada along the lakes as the Americans are now availing themselves of in Cleveland, Buffalo and other places.

Ore exists in Ontario in almost inexhaustible quantities, and the natural channels of transportation could not be bettered. A plant is being established at Collingwood, a small Ontario town on Georgian Bay. The plans contemplate the erection of four blast furnaces, one of which will be built immediately, and ten open-hearth steel furnaces. The number of men employed will be between two and three thousand. It is a significant evidence of the alertness of this company that they are also interested in developing the nickel industry in Ontario. The nickel district is near Sudbury, in Western Ontario, and is seventy miles long by forty miles wide. The deposits are irregular in character, and range from small pockets to acres in extent, rising, in places, to ridges and hills of solid ore. It is estimated that there is enough nickel now located to supply the world for the next hundred years at the present rate of consumption. Already these mines furnish over 40 per cent. of the world's supply. An influx of British capital into Ontario would begin a new epoch in the development of one of the richest sections of the Empire.

If the worst should come, and Great Britain should be destined to lose half her population, those who are forced to emigrate need not go outside the Empire, for Canada's greatest needs are British capital and British people. At present the Dominion Government finds the greatest difficulty in inducing Britons to emigrate to Canada, due partly to the widespread illusion that the western colony is a land of snow and ice. When Great Britain begins to send gold and settlers, manufacturers and workmen to Canada, she will find a way out of her present commercial crisis, and the truth will strike her that it is possible to build up a new industrial Britain in the west which will keep pace with American expansion of trade, and will establish more firmly than ever before the industrial power of the Empire.

MODERN CUPOLA PRACTICE

By Dr. R. Moldenke

THE forced production of to-day, the cry for tonnage, continuous melting for a week at a time, blast pressures threatening to run above a pound, with consequent poorer castings; in short, the desirability of making the capital draw interest for twenty-four hours out of the twenty-four, has given to modern founders a series of problems for solution which will keep the progressive end of the trade in a continuous mental tension, and bring about the slow, but certain, survival of the fittest. What wonder that veteran foundrymen sigh for the good old times of rectangular-sectioned, high, brick, natural-draught cupolas, with their freedom from emergency treatment, slow and comfortable heats, and most excellent, if expensive, iron.

The question of foundry economy, as met with in daily practice, is, in a great measure, dependent upon the personal equation of the owner or manager. One man equips his cupola house with an elevator, installs a positive blower, and arranges for an abundance of power. Then he buys cheap coke and scrap iron fit only to go into sash weights. Another man has a runway for charging, will buy no iron which must be handled by two or more men, practically trades most of his castings for scrap, and blesses Providence for the periodical fires which help him over his difficulties. Any boiler works will contract for a cupola upon demand. You are, however, expected to furnish the plans, otherwise a shell with some holes punched near the bottom and a wind box around them is the result, to the tune of prices equal to, if not greater than, those asked for the excellent cupolas made by reputable makers.

The melting cost is but a part of the bill of expenses incident to foundry work, and nine founders out of ten do not systematise their costs sufficiently to detect poor practice in this regard. He who knows at the end of each month just what every department costs per pound of castings sold will quickly inquire into inordinately large disbursements and apply the proper remedies. Given a well equipped foundry, proper organisation in the works and office, and a good management, the result will always be a genuine gold mine. Money is turned over quickly and often, manufacturing profits being seldom less than 10 per cent. for each transaction.

The starting point of the business naturally lies in the cupola practice, and a study of the development of this portion of the shop economy will bring out the principles which must be closely adhered to when striving for the fullest measure of success. The very name "cupola" explains the origin of the accepted designation for this variety of the shaft furnace. The melting zone being limited, this furnace could be charged continuously, if desired, were it not for the flame and gases issuing from the top. In other words, an apparatus amounting to practically a common salamander for heating purposes, but fitted with a refractory bottom and blast, had to be provided with a hood to protect the men. Right here we see that a careful study of all forms of the shaft furnace would be beneficial to cupola design. In fact, European practice differs from that of the United States mainly in the adaptation of suc-

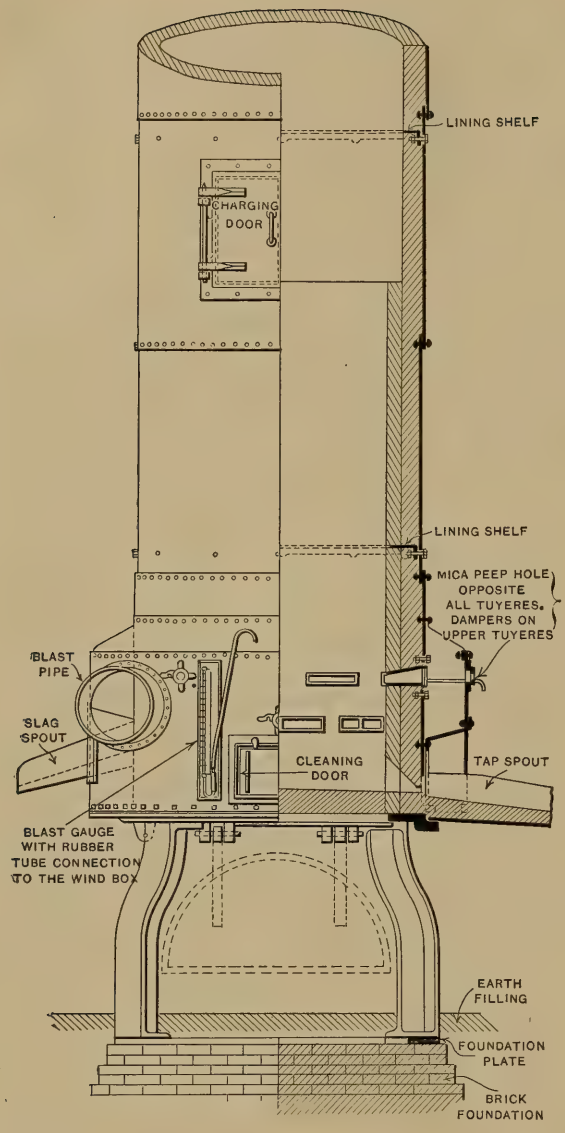


FIG. I.—CUPOLA MADE BY THE WHITING FOUNDRY EQUIPMENT CO., HARVEY, ILL., U. S. A.

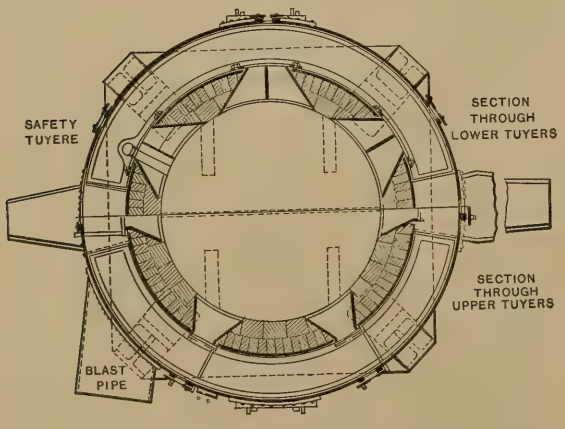


FIG. 2.—CROSS SECTION OF THE WHITING CUPOLA

cessful shaft furnaces for smelting copper and other ores to the requirements of iron founding.

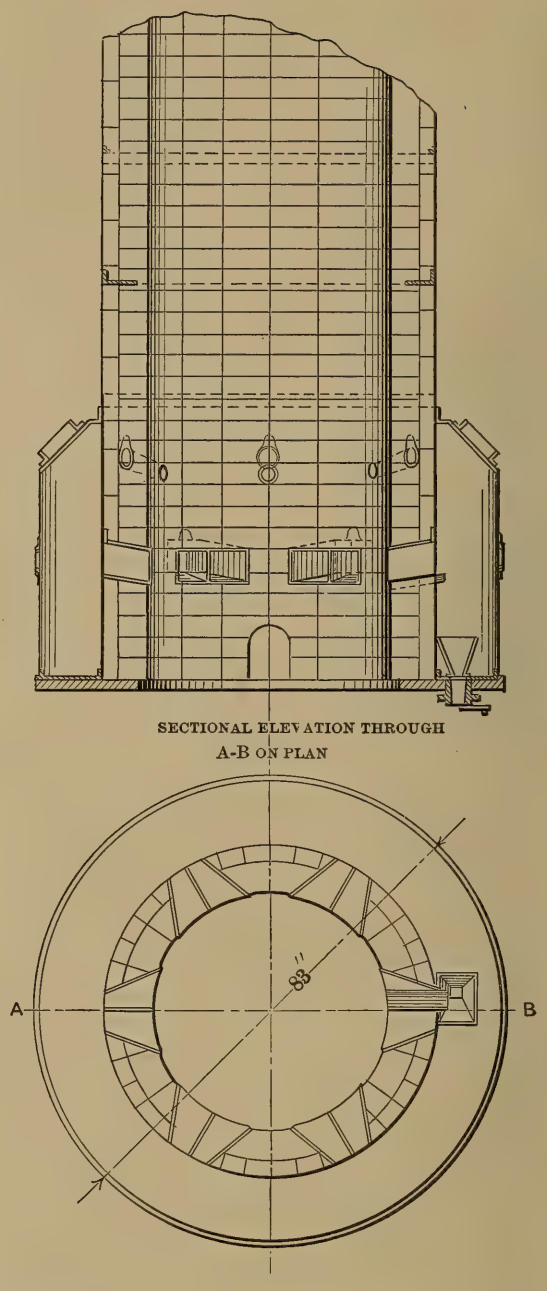


FIG. 3.—THE COLLIAU CUPOLA. MADE BY MESSRS. BYRAM & CO., DETROIT, MICH., U. S. A.

In looking over the numerous devices in use at the present time we see that the main point sought after is the complete and economical burning of the fuel; the secondary ones are the form of the cupola and the method of running it. It is conceded that as much attention is paid to-day to the melting ratio in the smallest foundry as will be found prevalent in the great western American smelting districts, where coke is bought at fabulous prices. This desire to get fuel economy is shared alike

by manager and foreman, and it would be a good move on the part of every superintendent to furnish his foundry foreman with a daily memorandum of the melting ratio, moulding loss, and shop labour cost per pound of good castings made. It would not only tend toward better economy, as it shows strict supervision, but would enable an efficient man to find the true line of demarkation between fuel waste, on the one side, and excessive economy, with resulting casting loss through cold iron, on the other.

Modern cupola practice is varied. The requirements of a pipe foundry casting 300 tons of iron daily are very different from the jobbing foundry with a 15-ton heat every second day. In each case, however, there should be the lowest possible shop cost for the castings. It would, therefore, be idle to commend one style of cupola as the best for all purposes. There are a certain number of requirements that all cupolas must be designed to meet; the proper balance of these for the case in hand alone will mean economical results.

The cross section of the cupola should be round, as there is a minimum of wear on the lining, as well as loss of heat. For very heavy tonnages, which were formerly melted in rectangular-sectioned brick cupolas, a round cupola, ten or more feet in diameter, provided with a good centre blast, will be found very efficient. The shaft itself should be cylindrical, the straight surface broken only by slight projections of brick just above the tuyeres, which should be carefully daubed into a gentle slope in going up, so that any melted iron which may descend along the sides is kept out of the tuyeres. The close adherence of the shaft to the lines of a blast furnace formerly in vogue has practically disappeared in the United States, though any number of cupolas, with

FIG. 4.—LOOKING DOWN INTO A CUPOLA PROVIDED WITH WEST'S CENTRE BLAST

widened and then contracted lines, may be found in Europe. From the nature of the case a widening in going downward from the charging door is not necessary, as there is no "hang" to fear, and the contraction of the hearth so essential to the furnace for blast pene-

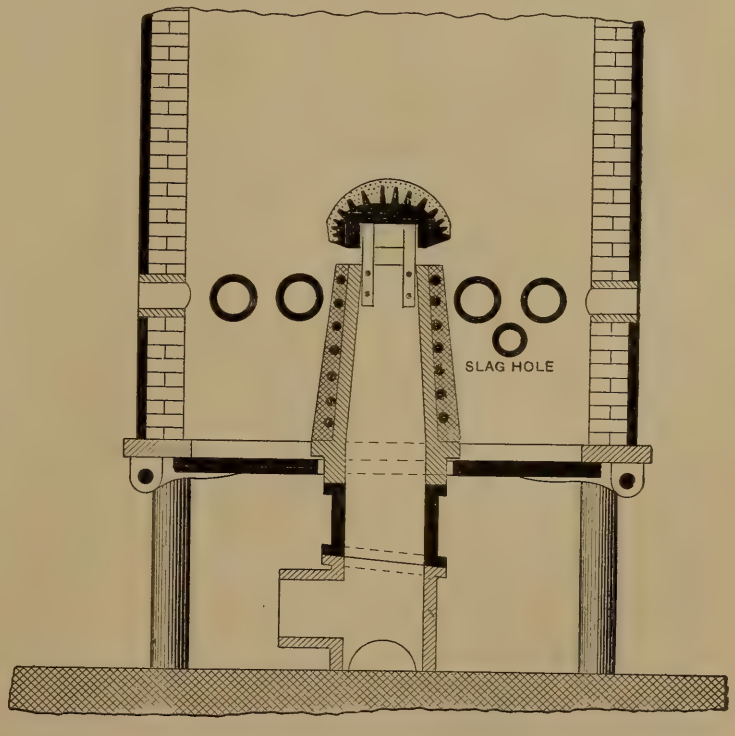


FIG. 5 —WEST'S "CENTRE BLAST" CUPOLA, MADE BY THE THOS. D. WEST ENGINEERING CO., SHARPSVILLE, PA., U. S. A.

FIG. 6.—IRELAND CUPOLAS IN THE SULZER FOUNDRY, WINTERTHUR, SWITZERLAND

tration purposes is not required for the comparatively open charges in even the largest cupola used to-day.

The arrangement of the tuyeres is highly important. From the three or four holes punched in the shell, about 18 inches above the bottom, to let in the air, we have come to well-designed tuyeres placed so that a maximum of air at a minimum pressure goes through the fuel nearly all around the circumference. Indeed, more than this, a second row of tuyeres a little distance above furnishes a further amount of air to insure complete combustion. Add the centre blast to this arrangement for air inlet where the diameter of the cupola is 60 inches or more inside the lining, and the best distribution of air possible is attained.

Blast pressures should be five ounces and upward. Either the fan or the positive blower will answer. The former is certainly cheaper and requires less power. Where, however, iron must be melted rapidly and the production pushed to the utmost, a positive blower, furnishing air at twelve to sixteen ounces, is essential.

The distance between the lower row of tuyeres and the bottom is an important one, for on this will depend the amount of iron it is possible to hold before it is necessary to tap. With a minimum of about 14 inches the chances of seeing iron coming out of the slag spout, or running into the wind box, if the former happens to be closed up, are very great. On the other hand, this distance is very economical in fuel. On the whole, the distance between the lower edge of the lower tuyeres and the bottom will average about 18 to 20 inches in the best practice.

As it is necessary to keep a bed of coke about 2 feet thick above the tuyeres at all times, the continuous melting systems, with 3 feet or more instead of only half that amount of space below the tuyeres, increase the fuel bill very much. The advantages derived, however, so far as freedom from "bunging up" long and heavy runs of melted metal are concerned, equalise matters

very satisfactorily. Of late, it has been customary to drop the charging door, or doors, if there are two, so low that no metal need be lifted. The best practice calls for one door on each side of the cupola, with the sill about 6 inches above the floor. This will prevent accidents, allow easy charging, and, by dumping alternately, insure a very good distribution. An electric hoist, preferably a double counterbalanced cage system, will be found very well adapted when there are two charging doors to supply.

Among the numerous cupolas in current use a few of the best are illustrated in this article. Only after the old blast-furnace type, with the incomplete combustion of the fuel, was abandoned for the modern system of melting in cupolas having a great number of tuyeres, so designed that the maximum of air is forced in with a minimum of pressure, can we say that a change for the better took place.

The distinctive difference between European and American cupola designs seems to be in the addition of a fore-hearth in the case of the former. In the United States they are accustomed to the "bull-ladle," which answers every requirement, and is cheaper to keep in repair. For irons which chill quickly or where a clean metal is particularly desired, it is a question if the European practice is not the best, provided the iron can be kept hot enough.

It is strange that the fore-hearth, which is so firmly established in American copper and silver smelting practice, yielding such an admirable separation of slag and metal, and throwing the burden of repairing where it can be done easiest, should not also have found favour among American iron smelters; yet such is not the case, and doubtless it is the fear of getting cold iron which is accountable for the situation.

Among the so-called "patent" cupolas in the United States the best known are probably the Colliau and the Whiting. Fig. 1 shows a typical American arrangement. It is a Whiting cupola. The arrangement of the double row of tuyeres flaring outward is shown in Fig. 2, in plan. A remarkably even distribution of air is thus obtained. Fig. 3 illustrates the Colliau design. Here we see, in plan and elevation, the arrangement of the lower and upper rows of tuyeres, the

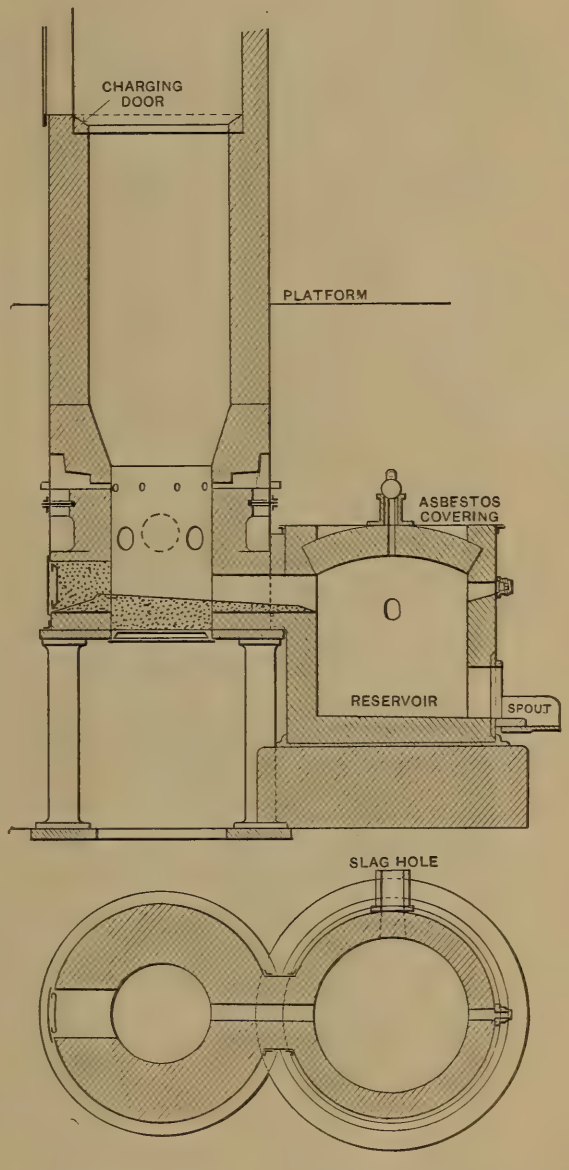


FIG. 7.—VERTICAL AND HORIZONTAL SECTION OF THE IRELAND CUPOLA

upper row in this case being smaller and intended for better penetration.

Those of us who are accustomed to producer gas will readily understand the meaning of the great flame seen issuing from cupolas having but one row of tuyeres. It is the old principle of gas making, the carbonic acid gas made at the tuyeres combining with more carbon from the incandescent fuel above

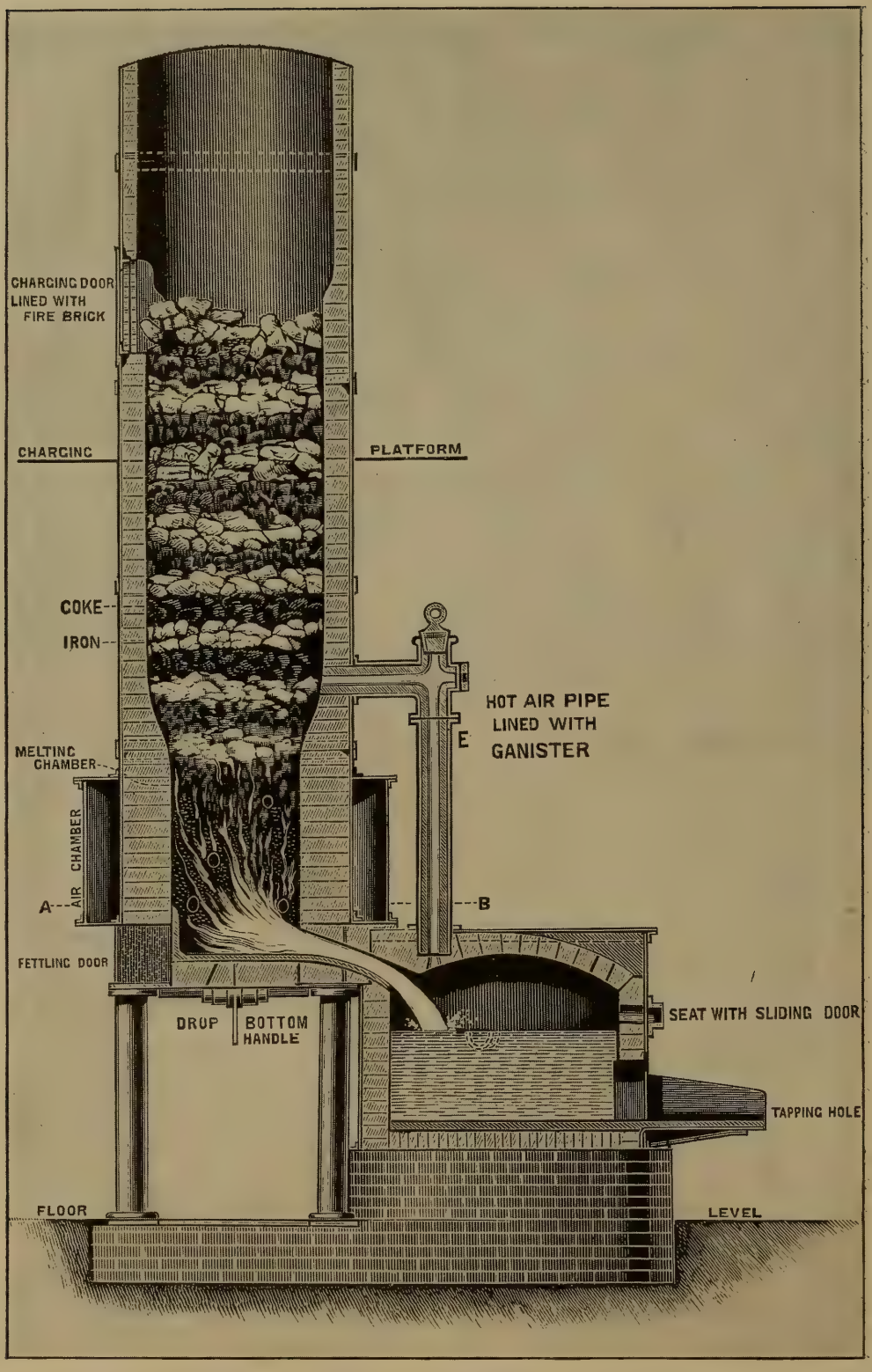


FIG. 8.—VERTICAL SECTION OF STEWART'S CUPOLA, MADE BY MESSRS. THWAITES BROS., LTD., BRADFORD, ENGLAND

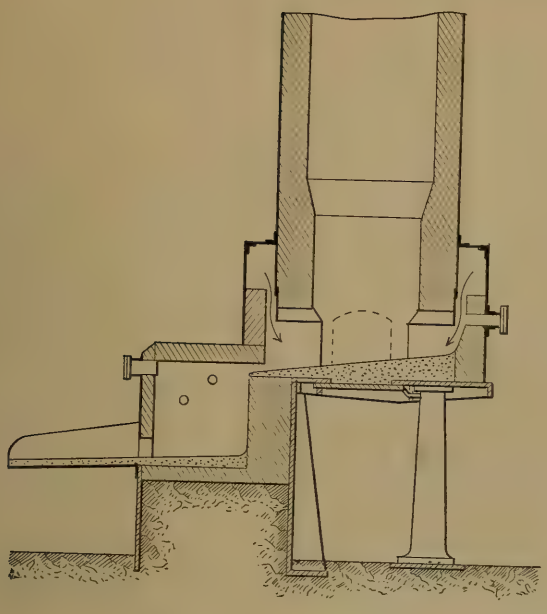


FIG. 9.—THE KRIGAR CUPOLA, MADE BY MESSRS. KRIGAR & IHSSEN HANNOVER, GERMANY

to form carbonic oxide. In other words, the common cupola is nothing more than a poorly constructed blast furnace without any ore to reduce, while it should be simply a melter. The second row of tuyeres furnishes the additional air to burn the carbonic oxide, and thus we get the full value of the fuel for heating up the stock above. One never sees a well-designed and managed cupola belching forth flame from the top of the stack.

Right here the writer cannot forbear to mention West's centre blast,—a most excellent device to introduce the blast into the middle of the charge. It is especially to be recommended for very large cupolas and wideawake cupola tenders. Fig. 5 shows a section through the arrangement, and Fig. 4 is peculiarly interesting, as it is a bird's-eye view into a cupola with a well-made bottom and crater-like lining, incidentally showing the cap of the centre blast pipe.

In Great Britain the Stewart cupola is best known; on the Continent we find the Ireland and the Krigar, with the Herbertz as a special type. Figs. 6 and 7 illustrate the Ireland cupola in use at Sulzer Brothers' foundry, at Winterthur, in Switzerland. In order to keep the iron in the fore-hearth hot, Stewart has added a hot blast, as shown in Fig. 8. This cupola, made by Thwaites Brothers, Ltd., of Bradford, England, enjoys a wide reputation in Europe. Fig. 11 shows the same cupola arranged for Bessemer practice, the fore-hearth being omitted. In the Krigar cupola, Fig. 9, we see the arrangement of a continuous tuyere, with the added advantage of freedom from slag troubles. This is a very good cupola, and is used extensively in Germany.

In Fig. 10 is shown the outcome of city foundry work. This excellently designed cupola is operated with a steam jet, and draws the air through the wind box surrounding the whole

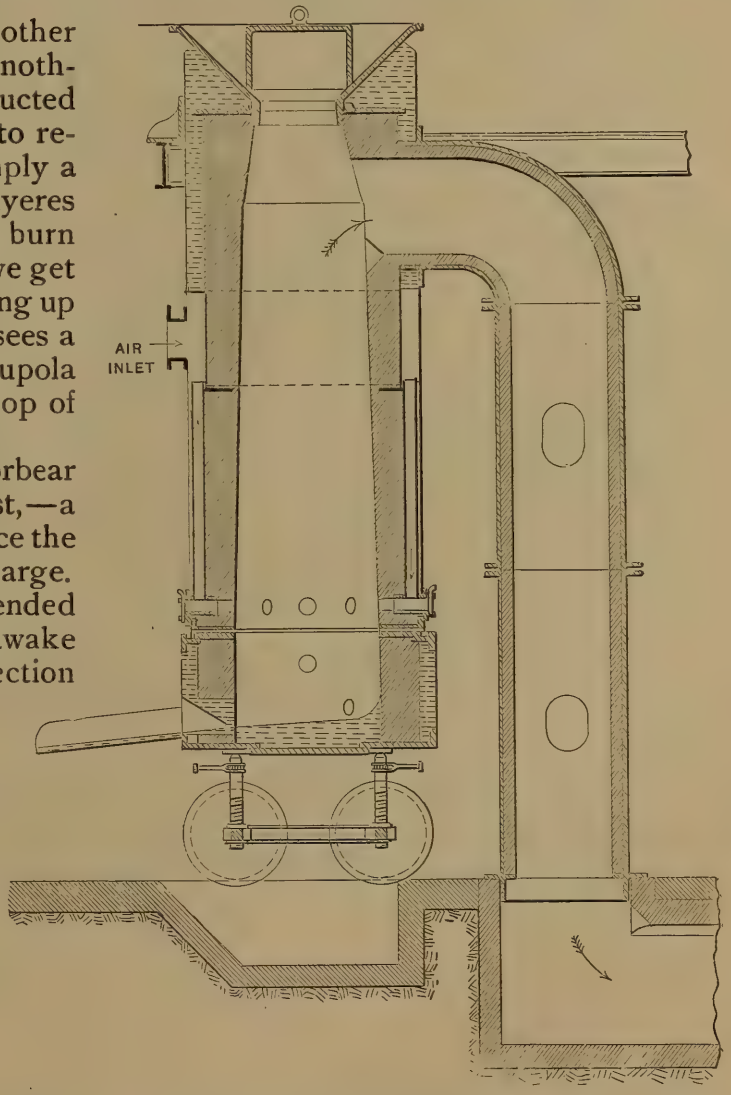


FIG. 10.—VERTICAL SECTION OF THE HERBERTZ CUPOLA, MADE BY F. A. HERBERTZ, KÖLN, GERMANY

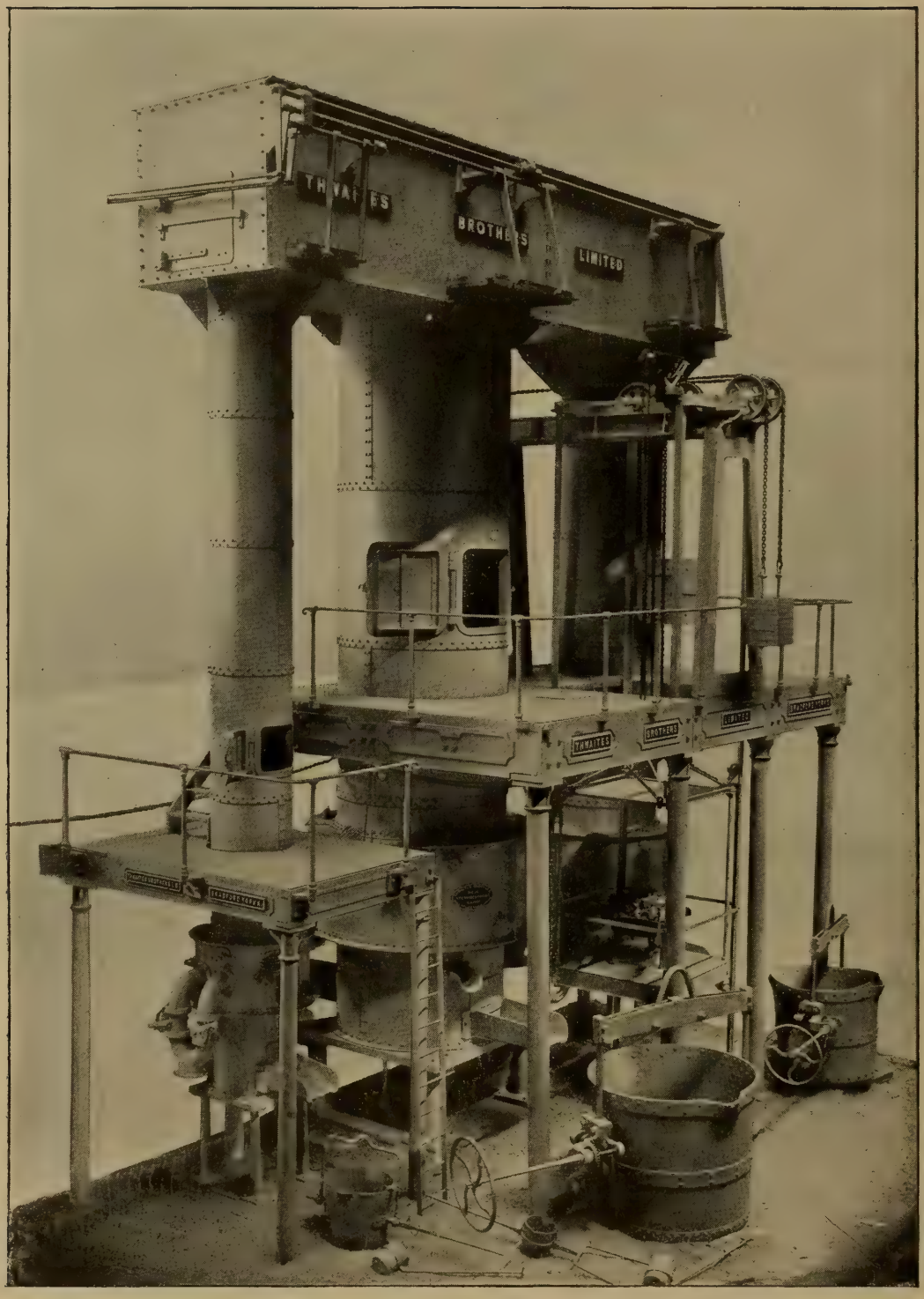


FIG. II.—THE STEWART CUPOLA ARRANGED FOR BESSEMER PRACTICE WITH THE FORE-HEARTH OMITTED

shell, and thus gets it preheated. Formerly the air was drawn through the slit between the bottom and the shaft proper. It is a very good and useful cupola for small diameters and output; for heavy runs it is altogether too expensive, so far as the writer knows from the trials that have been made.

Whether the fore-hearth is likely to be introduced into the United States is a question. The efficiency of well-designed American cupolas is so great that there has hardly been a call for this feature, which, after all, is simply for storage purposes. The excellence of iron and fuel in American practice enables great bodies of melted metal to be held in an open ladle for a long time, without deleterious results, for gray castings; and for the harder classes of work, such as rolls and "malleable work," the furnace is so much better adapted that the cupola is being gradually crowded out.

From centuries of inattention the foundry has, in the last decade, gone through a remarkable revival, and the end is not yet. So much can be said, however, that from being a much despised trade, an industry has been developed which ranks among the greatest. Through the ceaseless efforts of a few devoted pioneers an exact knowledge of the uses and limitations of this wonderfully varied product called cast iron has been given to the world, and to-day the foundry is respected by both the industrial and the scientific worlds.

ELECTRIC DISTRIBUTION FOR STREET RAILWAYS

A Comparison of Various Systems Made Before the American Street Railway Association

By C. F. Bancroft

THE cost of generating electric power, as regards fuel, depends to a great extent on the amount of power generated and the capacity of the generating apparatus with reference to the average output required. Under ordinary operative conditions, with the same power factor, that is, the same ratio of output to capacity, the cost of power per kilowatt-hour from stations of less than 500-KW capacity increases very rapidly as the station decreases in size. With from 500-KW to 1500-KW capacity, the cost of power per kilowatt-hour decreases slowly as the size of the station increases. From 1500-KW to 2500-KW capacity the cost per kilowatt-hour decreases very little as the output increases, and above 2500-KW station capacity the cost of power per kilowatt-hour becomes nearly uniform. This is due to the fact that in small plants the labour item is disproportionately large, and the general efficiency less than in larger ones, while in plants of 1500-KW output and larger the cost of labour remains proportionately nearly the same as the plant increases in size. It follows from this that there is often very little or nothing to be gained from an economical standpoint by substituting one station of 5000-KW capacity for two of 2500-KW capacity each, provided the local conditions as regards cost of coal, water, etc., are the same.

On a large system, requiring an average output of 12,000 kilowatts, even though the load be distributed within a 5-mile radius of a practical station location, it will usually be found economical to generate power at several smaller stations rather than at one large station, provided the conditions as regards cost of fuel, water, and real estate are about the same, as the cost of power station buildings and machinery per kilowatt of capacity and the cost of generating power per kilowatt-hour, with a station of 5000-KW capacity, is about the same as at a station of 10,000-KW capacity.

The interest on the saving in cost of feed wire by having several stations, each located near its load, would more than offset the slight saving in cost per kilowatt-hour, due to the generation of power at one large station, and it also has the advantage that in case of fire or accident to one station, the other can usually be so interconnected as to temporarily carry the entire load, and thereby avoid much of the stoppage of traffic which would occur if the road were supplied entirely from one station.

For an example of what may be called the standard 500-volt, continuous-current system of distribution, a city may be cited in which the street railway lines radiate west from the centre of the city like the spokes of a half-wheel, with a radius of about five miles. Instead of having one large station at the hub of the wheel, the road is supplied with power from seven stations, distributed throughout the system, having an aggregate capacity of over 26,000 kilowatts.

The generating and distributing system in use in one of the most densely populated cities may be taken as an example of the way in which the system of distribution adopted is governed by conditions outside of those indicated for the most economical generation and distribution of power to the car motors. Although this systm is compact, and will probably require an average station output of over 30,000 kilowatts, which, it would seem to the outside engineer, could be more economically distributed and almost as economically generated at several stations, the street railway company is installing a high-tension, alternating, direct-current system of distribution with a main station of 45,000-KW ultimate capacity, and five rotary converter sub-stations of from 3000-KW to 6000-KW capacity each. It is probable in this case that the location of the power station and the system of distribution was governed almost entirely by the great cost of real estate at points suitable for separate power stations.

It frequently happens that several miles distant from a street railway system much cheaper power is obtainable than at or near the centre of the system. This may be due to an available water power, or to a difference in the cost of fuel, etc., at two points. In cases of this kind the alternating, direct-current system, is usually the most applicable. To transmit power at 500 volts in any quantity from a distance of ten miles, or even less, is very expensive, owing to the large amount of copper required and the great loss. For instance, to deliver 500 ampères at ten miles distance will require about 150 tons of copper, allowing a loss of about 30 per cent. in the line. This same amount of power could be transmitted at 5000 volts by an alternating, direct-current system with about 5 tons of copper, and with a loss of less than 10 per cent. in the line.

The weight of copper required to transmit power a given distance, other things being equal, is inversely as the square of the voltage; that is to say, if it takes 100 pounds of copper to transmit a certain amount of power a given distance at 500 volts, it will only take twenty-five pounds of copper to transmit the same amount of power the same distance with the same loss at 1000 volts. It is owing to this fact that the alternating, direct-current system is so applicable where the power has to be transmitted for any considerable distance, as it allows of the use of very high voltages on the line, 10,000 volts or more being in general use, which, by means of transformers and rotary converters, can be reduced to 500 volts direct-current for the trolley wire at points where the power is required. For an example of this system of distribution, a street railway system may be cited which derives its power from a waterfall. Here the power is generated at a pressure of 2200 volts, and is stepped-up to 11,000 volts for the line. About 6000 horse-power is transmitted at this voltage for a distance of about twenty-one miles. The voltage is then reduced to 500 volts, direct current, by means of static transformers and rotary converters at five sub-stations, located at or near the points where the power is required.

What is known as the "booster"

system, is chiefly applicable on lines where there is a light average load, but where, for short periods, an extra heavy load has to be taken care of. It would seldom be economical to supply an entire road with power by means of a booster system, as the greater part of the power generated by the booster represents wasted energy, which is usually generated in an extravagant way, as the power required to drive the booster varies as the square of the current in the feeder; that is to say, if it requires 50 horse-power to drive the booster with a load of 100 ampères, it will require 200 horse-power to drive it if the load is increased to 200 ampères. Line losses which necessitate the continuous waste of more energy than could be compensated for by an ordinary compound-wound railway generator are seldom economical, even on a portion of a system; but there are many cases where there is sufficient copper installed to take care of the average load economically, but where for a short time each day, or for a few weeks in the year, owing to local conditions, the traffic is unusually heavy.

In cases like the above, where the heavy traffic is of short duration, a well-designed booster system may save a large investment in copper at a total cost of much less than would be required to pay the interest on the copper investment. For an example of this method of distribution a street railway company might be cited which supplies power to its own lines by means of a standard 500-volt, direct-current system, and which also supplies power to a smaller road about thirteen miles distant by means of a three-phase, alternating-current system, using 5500 volts on the line. Here the booster system is used in connection with the high-tension system. When it became necessary to repair the high-tension line, it was found expensive and inconvenient to do the work between the hours of 12 midnight and 4 A. M., the only time when the power was off, and as it was not considered safe to work on the line when it was in operation, a booster system was arranged to supply power to the distant road for short periods at times of light load. A 200-KW booster was installed at the generating station, and was designed to raise the voltage 1 volt per ampère of current. Switches were installed at the sub-stations so that the high-tension line could be connected directly with the 500-volt feeders, about eight miles from the generating station, and the booster was arranged so that it could be readily connected to the high-tension feeders.

When it was necessary to replace broken insulators or make other repairs on the line, the attendants were notified at the generating station and at the sub-stations, and at a prearranged signal, made by varying the voltage on the line, the alternators were thrown out and the booster thrown on in such a way that the power was off from the trolley wire only for a fraction of a minute. It was thus found quite practical to make repairs on the line while the booster was in operation, and the system proved very satisfactory for supplying power at times of light load, while repairs were being made, the load on the booster frequently running as high as 500 ampères, at which time the voltage generated by the booster was about 500, which, in addition to the 575 volts of the direct-current system, gave 1075 volts at the generating end of the line, the voltage at the sub-station averaging about 450. While it would have been very expensive to run this booster for any great length of time, for the short time it was used the total cost was much less than the interest on the copper investment required to build a duplicate line.

We may next consider the three-wire system, which is most applicable to double-track lines where one trolley is made positive and the other negative, there being about 1000 volts potential difference between the two, the current flowing from the positive trolley wire through the car motors to the rail and from the rail through the car motors and the other track to the negative trolley. The track is usually cross-bound, and also connected to the conductor connecting the two generators, which are

operated in series in the station. This connection with the track forms the third wire, and tends to equalise the voltage should there be more cars on one side of the system than on the other. This method of distribution is usually capable of saving from 20 per cent. to 40 per cent. in copper, according to the character of the track return. If well balanced, it also greatly reduces the electrolytic action on buried conductors, such as water pipes, and is most applicable where there are excessive track losses with fair opportunities for a balanced load.

There are few roads using the three-wire system of distribution, although it is used almost universally by lighting companies. This is probably due to the complications introduced in railway systems by the high voltage, usually about 1000 volts, between the trolley wire and feeders on different sides of the system and the difficulty of balancing the load. The saving in copper, while not as great as in the three-wire lighting system, is still enough to warrant the extra complication, and under favourable conditions may prove very valuable.

The writer is familiar with only one example of this system of distribution. In this case there is very heavy traffic over a double-track line to a park, about six miles from the power station. It was found impossible to handle the increased traffic on the ordinary 500-volt system with the existing feed wire. By reinsulating the line and operating it on the three-wire system, the efficiency of the distributing system was very much improved, and they were enabled to easily handle the increased traffic with the existing feed wire.

The alternating-current system seems peculiarly adapted to lines having long runs at uniform speed with few stops, such as lines connecting cities, rather than for ordinary street railway service. The alternating-current motors at present in general use are of the polyphase type, and require at least three working conductors, which is a serious objection in many cases for railway work, as it necessitates the use of two trolley wires in addition to the track as conductors.

The main advantage of the alternating-current system is the possibility of feeding lines with stationary transformers which need no supervision, but which can be considered simply as a part of the feeder, thereby multiplying many times the length of line which can economically be supplied with power from one station. The alternating-current motor also has the advantage of running at fairly constant speed independent of the load. It will not race going down hill if the power is left on, but will return power to the line, nor will it slow down much in going up hill.

The storage battery system, finally, is decidedly more expensive than the usual methods of electrical distribution, owing to the great first cost and the short life of the batteries. Lead is at present the only metal capable of resisting the attacks of sulphuric acid, and modern batteries consist largely of lead, which is very undesirable from a mechanical point of view, and is very heavy, so that unless the present type of storage battery is substantially improved, this system is likely to be used only where other systems are not practicable owing to peculiar local conditions or restrictions. The storage battery, however, has a large field in connection with the other systems of electrical distribution for street railways, and under favourable conditions may considerably increase the station capacity and reduce the fuel consumption, and when used on the line may greatly improve the regulation and increase the copper efficiency.

Current Topics

In the matter of the Belleville boiler in the British Navy, recently condemned by the Admiralty Committee on Boilers, the first three paragraphs of that committee's report make interesting reading, being to the following effect:—

"1. The committee are of the opinion that the advantages of water-tube boilers for naval purposes are so great, chiefly from the military point of view, that, provided a satisfactory type of water-tube boiler be adopted, it would be more suitable for use in His Majesty's navy than the cylindrical type of boiler.

"2. The committee do not consider that the Belleville boiler has any such advantage over other types of water-tube boilers as to lead them to recommend it as the best adapted to the requirements of His Majesty's navy.

"3. The committee recommend:—*a.* As regards ships which are to be ordered in the future, that Belleville boilers be not fitted in any case. *b.* As regards ships recently ordered, for which the work done on the boilers is not too far advanced, that Belleville boilers be not fitted. *c.* As regards ships under construction, for which the work is so far advanced that any alteration of type of boiler would delay the completion of the ships, that Belleville boilers be retained. *d.* As regards completed ships, that Belleville boilers be retained as fitted."

Curiosity as to the action that the government would take on the receipt of this report was set at rest by the announcement that the Admiralty intended to make the changes recommended by the committee, and there remain thus for present consideration simply some of the defences set up for the Belleville boiler by its friends. These have been disposed of in *The Engineer*, of London, as follows:—The defenders of the Belleville boiler say that its weaknesses and defects are common to all water-tube boilers. This is not true. That water-tube boilers suffer more from corrosion than other steam generators may be conceded as a general truth, but there similarity of defects ends. The Belleville boiler is a very special type of steam generator. It has special and particular defects of its own, shared with it by no other boiler in any considerable vogue. Indeed, we are not aware of the existence of any type of generator which resembles the Belleville boiler further than that there is water inside tubes instead of outside of them in both. It must be remembered that the water-tube boiler is as old as the days of Oliver

Evans. It is probable that twice as many patents have been taken out for water-tube boilers as for any other boilers; and certain facts have been learned by experience, and certain rules of construction and principles of design have been formulated, which must be observed if trouble is to be avoided. It is necessary to insist on the fact that the Belleville boiler is constructed entirely without regard to these principles, because it seems to be probable that exception will be taken to the water-tube boiler in general, as being unsuitable for British warships. The objection will be based on the experience had with the Belleville boiler. It must be made perfectly clear, therefore, that the Belleville boiler is quite unlike any other water-tube boiler. It may be said, indeed, that water-tube boilers can be divided into two groups or species In one is the Belleville boiler, standing alone. In the other group are at least a dozen water-tube boilers which have all been found satisfactory in the main. To condemn the one group because the other has failed would be as prudent and as intelligent as it would be to condemn Scotch boilers in the mercantile marine because locomotive boilers have not been a success in merchant ships.

THE great difference between the Belleville and all other boilers is as easily stated as it is easily overlooked or forgotten. It may be taken as proved that in every water-tube boiler whose tubes are set at a small angle with the horizontal the length of the tube must not exceed twenty-four diameters, and the nearer the tube is to the horizontal the more essential is it that this rule should be observed. We can cite cases where the tubes are much more than twenty-four diameters long. In these cases, however, the boilers are very easily worked, and the rate of evaporation is comparatively low. These favourable conditions do not obtain at sea, and we have only marine boilers to consider just now. We have in mind numerous instances, however, in which the rule has been broken, even when the boiler was not hard pressed, and the results have been bent and burned tubes, and constant leakage. If the tubes must be long in proportion to their diameter, then they must be vertical, or nearly so, as in the Thornycroft and Yarrow boilers, and many others constructed on the same lines far too numerous to mention. Furthermore, it is a fundamental condition of efficient service that the ends of the tubes shall be open, so that the steam can escape at one end and the water enter at the other with the utmost freedom. If our readers who are versed in the generation of steam will call to mind the different types of water-tube boilers now abounding, they will see that one and all at least ostensibly claim to fullfil these conditions; and they are one and all in the main good just in proportion as they fullfil the conditions completely, and bad in the main just in proportion as they do not fullfil them.

THE Belleville boiler sets all these principles at defiance. It is in this way *sui generis*, unique. Each "element" consists of nine or ten tubes inclined 2 degrees or 3 degrees from the horizontal. These tubes are from 7 feet to 10 feet long. Taking the best types, we have a total length of tube of $9 \times 7 = 63$ feet; the tubes are about 5 inches in diameter; thus the ratio of diameter to length, instead of being 1 to 24, is 1 to about 150; and, to make matters worse, there are short reversals of current at each end of each length of tube. Now the longer the tube the more necessary it is that the utmost freedom for the entrance of water and the exit of steam should be provided. But in the Belleville boiler the supply has to enter through a small nozzle at the lower end and to escape through a similar small nozzle at the upper end of each element. Precisely why M. Belleville adopted this system it is impossible to say. As a hot-water arrangement for heating buildings it would, no doubt, work very well. The history of the Belleville boiler will

be found in Chapter XI. of M. Bertin's treatise on "Marine Boilers," and very curious reading it is. We are not now writing to find fault with the Belleville boiler. That, in the light of recent events, is wholly unnecessary. Our object at present is to reassure those who are doubtful of the merits of water-tube boilers by making it quite clear that the Belleville generator has practically nothing in common with any other water-tube boiler. Its defects are all its own, as are its merits,—if it has any.

One word must be said in conclusion; the Boiler Committee, in their report, condemn the automatic feed apparatus. An attempt has been made to show that it is not worse than the apparatus affixed to other boilers. Now, as a matter of fact, almost all, if not all, other water-tube boilers can be, and are, worked without automatic feed gear; but, furthermore, the automatic apparatus used by such makers as Yarrow, Thornycroft, and Mumford are simplicity itself compared with the Belleville mechanism. Again, it has been stated that difficulty in reading the water level in a gauge glass is peculiar to all water-tube marine boilers. This is simply untrue. The arrangements of the steam receiver in the Belleville boiler are such as to render it difficult to know where the water is; but, as a matter of fact, there is never any constant water level, nor indeed any true water level at all in the Belleville boiler. The five lower rows of tubes are supposed to contain water, and the upper rows a mixture of water and steam. The whole theory of the boiler is happy-go-lucky. It is supposed that there will always be enough water in a tube to keep it cool, if not at the moment, then in a few seconds. The most that the gauge can do is to prove that there is some water in the boiler, but what the distribution of that water precisely is no one knows

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Considering the extended application that has been made during the past twenty years of the principles of steam jet engineering, it is worth recalling that this branch of engineering is an art of very old standing,—one of those things of which the ancients knew more by far than we are apt, ordinarily, to give them credit for. The primary object of Hero's boiler of 2000 years ago was, indeed, the production of a steam jet, and those portable steam machines which were named "eolipiles," from Eolus, the god of wind, and from their application to create artificial winds, appear to have rapidly come into extended use about that time. Among the Romans they were employed as bellows for exciting fires, and as this was not for want of the latter instruments, they must have had properties which made them preferable, on some occasions, to bellows. One, perhaps, was their occupying little room on the hearth; and another their requiring no attendant to keep up the blast. Ewbank, in his interesting book on "Hydraulics and Mechanics," tells that, besides blowing directly upon, or against, a fire, eolipiles were employed to increase the draught of chimneys, for which purpose the jet of steam was made to rise perpendicularly from the centre of the top of the boiler, the latter being placed on the hearth and heated by the fire. Sometimes those designed for this purpose had a handle to suspend them over the fire. With the presumably common use of this apparatus in Herculaneum and Pompeii, and the prevalence of ancient customs in Italy, it is, perhaps, not to be wondered at that similar apparatus was much employed in that country as late as the seventeenth century "to cure smoaky chimneys, for, being hung over the fire, the blast arising from them carries up the loitering smoke along with it." Here we have clearly a Middle Age application of the modern chimney steam jet idea.

But there were other uses of eolipiles in those early days. Some were made of gold and silver and other costly

metals, and were filled with scented water "to cause a pleasant temperature, to refresh the spirit, and rejoice the heart, not only of the healthy, but also of the sick." Rhenanus, an old German writer, who died in 1547, enumerating the treasures belonging to the ancient church at Mentz, speaks of eolipiles in the form of "silver cranes, in the belly of which was put fire," and which gave out "a sweete savour of perfumes by the open beake." Perfumes were sometimes disseminated in the old amphitheatres by being mixed with boiling water so that the odour rose and was diffused by the steam. Shakespeare clearly indicates that perfuming rooms was common in his time, the neglect of cleanliness making this necessary, and it is probable that the same processes were used as those mentioned by earlier writers.

EOLIPILES were also employed to produce music. By adapting trumpets, flutes, clarionets, and other wind instruments to the neck or orifice of an eolipile they were sounded as by currents of air. This application of the eolipiles was probably coeval with their invention. It is, indeed, only a variation of the supposed musical apparatus of the Memnonian Statue, and of the devices described by Hero. All the old writers on eolipiles mention it. Fludd figures a variety of instruments sounded by currents of steam, and Rivius, after noticing the use of eolipiles for blowing fires and fumigating rooms, observes that "they are also made to produce music, the steam passing through reeds or organ pipes so as to cause astonishment in those who have no idea of such wonderful operations." Gerbert applied eolipiles, in place of bellows, to sound an organ at Rheims in the tenth century, and the instrument appears to have been extant two hundred years afterwards.

FROM the observations of one of the early travellers in the East it seems that eolipiles were employed even in war and with great effect. Carpini, in the account of his travels in the year 1286, describes a species of eolipile of human form, and apparently charged with an inflammable liquid, as having been used in a battle between the Mongals and the troops of Prester John. The latter, he says, caused a number of hollow figures to be made of copper, which resembled men, and, being charged with some combustible substance, "were set upon horses, each having a man behind on the horse with a pair of bellows to stir up the fire. When approaching to give battle, these mounted images were first sent forward against the enemy, and the men who rode behind set fire to the combustibles by some means, and blew strongly with their bellows; and the Mongal men and horses were burnt with wild fire and the air was darkened with smoke." Supposing these eolipiles to have been charged with alcohol or spirit of wine, they must have been of telling effect, as the jet of flame might have been made to extend to a distance of 25 or 30 feet.

THE making of weldless chains by passing metal bars of proper section through rolls which are practically a series of dies, each punching pieces out of the bars so that ultimately perfect chain links are produced, has been before the public more or less prominently for the past ten years. It is interesting, however, now to learn from *Engineering*, of London, that large works have recently been erected at Lemington-on-the-Tyne for turning out chain cables after this manner. The bars are heated in a furnace 70 feet long, and are drawn direct into the rolls. In the course of its passage a bar of this length, weighing nearly two tons, is rapidly converted into a red-hot 1¾-inch cable 90 feet long, link within link without weld, and with the stud already in its place in each link. The links are connected by webs and fins, which are afterwards removed cold by punching and special planing machines. It is claimed that a cable made in this manner from the usual ship

quality of steel is 50 per cent. stronger than the best welded iron cable of the same size, and that it is also very tough. The works have a frontage on the river of 1000 yards, and are equipped with powerful machinery. The rolling-mill engines have 48-inch cylinders and drive a mill weighing over 250 tons. There are punching machines for removing the fins from the links, and a special planing machine for cutting the inner connections. The principal machines have been specially designed for this work and patented in many countries.

SPEAKING recently before the "Get-Together Club," at New York, on industrial betterment as practised at the works of Messrs. J. H. Williams & Co., of Brooklyn, New York, makers of drop forgings, Mr. William C. Redfield, the treasurer of the firm, after telling of their bathing and wash rooms for the men, their system of prizes for suggestions for improved methods of turning out work, their accident-preventing devices, means of fire protection, and other details similarly interesting, and all of them having the interests of their employees in view, said:—"All this is nothing, compared with the fact of just and fair treatment. We usually advance wages voluntarily; have never had a general demand for advanced pay; have never made a general reduction of pay. Those who know factory conditions will, however, think most of the fact that we have never cut piece-work rates. We have not thought it just or wise to do so. We have recently, unasked, put our works on a nine-hour day with ten hours' pay, working fifty-four hours weekly at the wages heretofore paid for sixty hours; this has, so far, proved profitable; our output is, if anything, larger than before. These things are done, not as charity, but as matters of justice, as privileges, and as sources of profit. He who has many opportunities is in honour bound to share with those who have few. It is pleasant and profitable so to share. We shall continue along the lines suggested, because we like it and because it pays to do so. It pays, because a man is more than a machine. It pays, because the rate of wages is not the chief factor in cost, but rather the rate of production. A clean man produces more, in the long run, than a dirty man. A well-informed man produces more than an ignorant man. A justly-treated man produces more than one who is unjustly treated. A contented man is a better and cheaper producer than a discontented man. A well-paid man is a more economical producer than an ill-paid man.

"IF, on piece work, a man of skill and energy increases his pay largely, we think him entitled to such increase, for we economise fuel, interest, and other important items. It does not seem quite honourable, if he thus profits, and we also, for us to cut away his profits that we may gain much more, nor do we believe it pays. In our industry repairs count largely, and a well-paid man will so care for machines as to minimise the need for repairs, because he loses by the time taken for such repairs; he does not waste material, for often in our processes he may waste his own valuable time when he wastes material. We find, also, that justly paid men save in the important item of imperfect work. Our force replace in their own time work that is bad, and pay for the material. Thus, saving, as we do, in material, repairs, interest, fuel, and other ways, we think justice to the workman demands that we shall not cut the piece-work rate merely because he makes well thereby."

IN the old days an apprentice was able to acquire a thorough, all-round knowledge of a trade in one shop. This, however, is becoming increasingly difficult to do, and in very many cases it is now quite impossible because of the intense specialisation of modern establishments, an argument being thus supplied in favour of technical education which

is intended to take the place of apprenticeship. More than this,—technical education aims to supply an exact knowledge of the scientific facts which underlie the practice of crafts, in this way substituting scientific methods for the old rule-of-thumb practice. There are thus two sides to the question, the scientific or theoretical, and the practical or workshop training. The best technical schools are equipped for teaching both. In considering the adaptability of this method of training for workmen, one is compelled to the conclusion that it is not universally applicable. From the point of view of workshop conditions the question may be asked, to what extent will it help the machine minder who supervises the production of the one-thousandth part of a watch, or of the one-hundredth part of a pair of shoes, or some fractional part of a type-writer, or who supplies stock to an automatic machine? However intelligent a man may be, his pace is set by the machine which he minds, and by which his action is controlled. The possession of the best education will not enable one man to compete successfully with another if the latter minds a machine that is turning out double or treble the product of the former. But technical education, it is said, will enable such men to advance their position,—to take the lead of their fellows, and so on. In that case they cease to be workmen, and the question is no longer one which concerns the training of men, as workmen, to compete with those of other nations. Technical education is a good thing in itself. But it is no more a universal cure than is the nostrum of the quack for all the ills of humanity. It must always, in the present trend of industry, be subordinated to the great and paramount machine question.

THE special value of technical education appears in the training of men for those trades in which handicraft still retains an important place. In the various departments of engineering, in joinery, in sheet metal designs, in shipbuilding, in jewelers' work, in dyeing, bookbinding, upholstery, carriage building, carving, and other artistic trades, it is of immense value. And the more so, too, as the difficulties of learning a trade in the modern factory increase. Every now and again the cry goes forth that leading, all-round men, suitable for foremen and managers, become more scarce. As you cannot grow grapes on thorns, neither does the modern system tend to develop richly endowed men. Yet all firms need a few controlling and guiding minds of a superior order, imbued with mechanical genius, and highly experienced in practice. These are the men for whom, in modern shops, it is increasingly difficult to provide the training that was obtainable in the shops of earlier days. Here the technical schools fill a useful place. The development of such men in the future will be largely aided by the schools, in which they may obtain grounding in principles and learn something of diversity in practice.

PERHAPS the passing of apprenticeship and the growth of technical education in its place may not, in the evolution of industry, prove any more regrettable than that of many contemporary features of mediæval life which have also vanished. The apprenticeship system has fostered a very narrow life. Once a workman, always a workman, has been the prevalent tradition. A man trained in one craft must never cross the border line and dabble in another. No matter how urgent the necessity, or how serious the delay involved, the proper man must be sent for, lest the bread should be taken out of the mouth of a fellow-workman. This spirit has always ruled, and rules to-day as dominant as ever in British shops. Only recently a young employer disapprovingly pointed to a technical article in a journal, written by one of his foremen on a subject outside his own trade. "This is not pattern making!" When employers are imbued with this narrow spirit the men can hardly be expected to rise above it. Things are worse now

than in the old days, when lads were taught a trade in its entirety. Instructing them in minute sections of a trade leaves the mind but half occupied, and is largely responsible for that narrowness of view and pig-headedness of which employers feel the effects when they want to introduce better methods. If apprenticeship is passing away from modern industrial training, out of its death will, perhaps, grow a broader ideal of craftsmanship.

WALTER MARTIN McFARLAND

A BIOGRAPHICAL SKETCH

By George W. Melville, Engineer-in-Chief and Rear-Admiral U. S. Navy

DURING my tenure of office as Engineer-in-Chief of the Navy, extending from August 9, 1887, to the present time, there have been constructed, or are now building, for our fleet 138 vessels of all types, with an aggregate horse-power of 948,728 and a total displacement of 481,028 tons. When this work is considered from the viewpoint of our unpreparedness as a nation, at its inception,—not to purchase, but to produce the multitude of components which make up the modern ship-of-war, her hull, enginery, armour, and armament; and when it is remembered that scarcely a vessel in this fleet carries, in any form, a pound of foreign metal,—that the ships are American, from keel to fighting top,—there will be realised the magnitude of a task, which, even in its early history, *Engineering*, of London, described as "one of the most remarkable features in the peaceful records of modern navies."

Within this period also the nation has met the shock of war, which, though of brief duration, has widened indefinitely the boundaries of this Republic and has unfurled its flag, for all time, above West Indian and Asian lands. That war, too, was, in large degree, naval; its demands were met and its successes won only by an expansion of the fleet so swift and large as to strain, to the elastic limit, the resources and energies of the bureaus charged with its development and maintenance. Finally during my years of office, through the passage of the Personnel Bill, the regrettable strife within our navy has ended; "Peace with honor" spreads her wing above now-welded factions; and engineering has found its rightful place and recognition in our fleet.

I recall, at this time, these labours and conflicts of the past, and note the extent of the duties of the Bureau of Steam Engineering to-day, with no reference to my own part in them; but to show that a successful work of such magnitude has been, and is now, made possible only by the loyal support and the skilful and untiring co-operation of the officers who have formed, or now compose, my bureau staff. If I have been the leader in the engineering toil and struggle of these years, Israel has prevailed, not through my effort only, but, as well, through the fidelity of those who, in time of stress, have upheld my hands "until the going down of the sun."

Among the foremost of these men has been Walter Martin McFarland, and, at the request of the editor of CASSIER'S MAGAZINE, I write, with pleasure, of his service. McFarland was born in Washington, D. C., in 1859. He is of Scotch-Irish descent, and shows the able and virile qualities of that race. His early education was received in the public schools of Washington, from which he passed to the

preparatory department of Columbia University, winning the Kendall Scholarship of 1874 by competitive examination. In 1875 he entered the United States Naval Academy as a cadet engineer, and was graduated in 1879, second in his class His sea service comprises duty on the North Atlantic and European stations, 1879–81; in the U. S. S. *Michigan*, on the Lakes, 1882–83; on the Pacific station, 1886–88; and again, on the European station, 1894–96. He was commissioned as assistant engineer in 1881; as passed assistant engineer in 1891; and as chief engineer in 1898, being then the youngest officer, for more than twenty years, to reach that grade, and receiving the highest examination-mark ever given in promotion to the latter. In 1899, after the passage of the Personnel Bill, he was commissioned a lieutenant; but, in that year, resigned to enter the Westinghouse Electric and Manufacturing Company, of which he is, at this time, an acting vice-president.

While I cannot but congratulate my good friend, George Westinghouse,—whose name is a synonym for engineering genius and business enterprise,—on McFarland's entrance into his official corps, I cannot but regret the loss to the fleet of one of its brightest men, and to myself of a most talented and loyal assistant, who passed from the navy to serve his country, doubtless some day as a "Captain of Industry" in the ever-widening field of American manufacturies.

McFarland's shore duty, while in the navy, was as varied as his ability is versatile and his energy is untiring. His first service at the Bureau of Steam Engineering was in 1882. From 1883 to 1885 he was detailed from the navy as assistant professor of mechanical engineering at Cornell University, Ithaca, N. Y. On the completion of his term the Hon. Andrew D. White, then the distinguished president of the university, requested an extension of his service; but the requirements of sea-duty forbade. The years 1885–86 were occupied with the inspection of machinery then building and with work on preliminary designs for proposed vessels. From 1889 to 1894 he was again attached to the bureau, serving, during the greater part of that period, practically as the private secretary and confidential assistant of the engineer-in-chief. During the years 1897–98 these duties were resumed, after a cruise at sea.

It will be seen that McFarland's naval career covered a period of twenty-four years, divided about equally in service ashore and afloat. In this sketch I shall refer principally to the pleasant years which are best known to me, and during which he served with me in Washington. He was first assigned to duty in the draughting room; but his abilities in other important directions soon became so evident that his actual work as a designer closed, since attention to the multitudinous details of that most arduous duty will occupy the full time of the most talented officer. However, during his years at the bureau he maintained always a keen interest in the designing room, and kept track of the general trend of its work. Thus, while acting largely as my "right-hand man," relieving me of much correspondence, carrying through numberless tasks of a most varied nature, he managed still to make many calculations and to check generally my solution of the many technical problems which daily presented themselves.

As will later appear, his knowledge and abilities were not limited to marine engineering *per se*. It is, perhaps, a truism to say that the acquaintance with pure and applied science which is possessed by the able practitioner in any branch of engineering equips him for service in many and varied fields of intellectual endeavour. So it was with McFarland. Indeed, I have never had an assistant who, while having a complete understanding of the duties of his own bureau, was better acquainted with the general work and scope of every section of the Navy Department and of allied branches of engineering which pertained thereto.

To recapitulate, in detail, the service of these years would be to recount,

more or less, the history of every branch of the Bureau of Steam Engineering, since all have felt his touch. This was true, to a great extent, of external work, as well. There are few naval officers who escape "Board" duty, and McFarland had a sort of life-membership on them. He was sent constantly to the various navy yards, shipbuilding and steel works, to provide for the adjustment of engineering matters, uncertain or in dispute; and his tact, sound judgment, and quick decision were of the utmost service. Besides his routine, and such extraordinary duties as the above, he acted as secretary-treasurer of the American Society of Naval Engineers and as editor of its *Journal* during the years 1890, 1892–3, and 1897. The laying-out of the form and policy of this *Journal* and its subsequent success were due largely to him. For such work he was thoroughly equipped through his ability as a writer, and the wide knowledge acquired by steady reading of current technical literature.

McFarland was the lecturer on marine engineering at the Naval War College, at Newport, R. I., during the session of 1894. His lectures were republished, in full, in several technical journals. He was also the delegate representing the United States Navy Department at the International Congress of Naval Architects and Marine Engineers, at London, England, in July, 1897. During the World's Fair, held at Chicago, Ill., in August, 1893, I had the honour of serving as chairman of the Division of Marine and Naval Engineering and Naval Architecture. In the work of organisation, during the sessions, and in the publication of the proceedings, McFarland, as official secretary of this division, was one of the most potent factors in its marked success. His alert mind, winning courtesy, and untiring energy drew forth such comment as the following, which I quote from the issue of *Engineering*, of London, for November 24, 1893:—

"Dr. Elgar called attention to the great amount of labour that the proceedings of the Congress put upon the president and upon the secretary, Mr. W. M. McFarland, U. S. N., and predicted that the volume in which these would be published would form one of the most varied and instructive collections of papers on naval engineering ever got together. Colonel N. Soliani, Engineer-in-Chief of the Italian Navy, supported Dr. Elgar's remarks. * * *"

The correspondent for *Engineering* then quotes the *Marine Review*, of Cleveland, Ohio, thus:—

"With such young men around him as Passed Assistant Engineer McFarland, it is no wonder that Commodore Melville is credited with having accomplished a great deal more than any of his predecessors in the navy. Although giving every evidence of the greatest respect and loyalty to his chief, Mr. McFarland's manner of carrying out the duties of the office of secretary of the Congress was such as to cause most favourable comment from nearly everybody in attendance. He is certainly regarded as among the brightest young men in the navy, and is destined for a position of more than ordinary importance. It is unfortunate, in view of his valuable service in Washington, that he is soon to go to sea."

The correspondent for *Engineering* then continues:—

"The writer, being personally acquainted with Mr. McFarland, can most heartily endorse every word of the above well-deserved compliment."

To this I may add that, pressed, as I was, with many official duties of a varied nature, McFarland's skilful aid in the whole matter of this Congress,—its organisation, conduct, and what-not,—was of the greatest value to me; and to it I attribute much of the success which attended the work of this division of the Congress.

In November, 1897, the Secretary of the Navy assembled the "Personnel Board," with Vice-President Roosevelt,—then Assistant Secretary of the Navy,—as its presiding officer. The duties of this board were to consider and advise upon the reorganisation, on modern lines, of the naval personnel. Its membership comprised some of the

most distinguished officers of the line and engineers, and, among them, McFarland had the honour of acting as the sole sponsor for the younger men of his corps.*

The main result of the deliberations of this board was the recommendation for the adoption of the so-called "amalgamation scheme," *i. e.*, the union of the former line and former engineer officers in a single combatant corps of what Colonel Roosevelt aptly termed "fighting engineers." In the development of an engineering navy in an age of engineering the amalgamation idea was wholly sound; for, aside from the necessity of giving the modern naval engineer military rank and title and military command of his men, it was, further, but a natural step to extend the engineering work of the modern line officer in steel inspection, ordnance, the care of electric auxiliaries, etc., to include as well the motive machinery, the very "vitals" of the ship he handled and fought.

From the first, McFarland was one of the most active and efficient supporters of the amalgamation plan. As a member of the board, he had the especial confidence of its president, Colonel Roosevelt; and he proved a powerful advocate of the measure before Congressional committees, drawing from them the comment that he was the best posted man they had ever examined. In the press, also, in the pages of this magazine, and in other periodicals, his timely and forceful arguments appeared for the eventually successful plan which, then, he had so much at heart.

McFarland's only opportunity, while in the navy, to fight for his country, to feel the shock of conflict on the sea, and to put to the crucial test theories formed from the study and research of his strenuous life in peace, came with the outbreak of the Spanish-American War. He was, at that time, practically my principal assistant; and I take it as part of my duty, in writing now, to record the fact that I compelled him to stick to his post at the bureau. Like every worthy naval officer whose services on shore were such that he could not be spared for sea duty, McFarland was most eager to be on a battleship "at the front," off Santiago or elsewhere; but his readiness, resource, and knowledge of bureau work all combined to make his aid, during that period of exceptional activity and stress, invaluable to me, and his request for sea duty was, perforce, denied. In referring, in my annual report for 1898, to the faithful service rendered by officers of the Engineer Corps who were forced to remain ashore during the war, I said, in effect, that it was due to them, for the loss of glory consequent upon their absence from the actual fighting, that a public record be made by me of their sacrifice of personal interest to the general good; and this public record I take care here to repeat, with regard especially to McFarland. As a matter of fact, his war duty was most important, and of the highest value to his country; for, while aiding me so greatly, he was also of much service to the Assistant Secretary of the Navy in the matter of the purchase of vessels for the auxiliary fleet, in which extensive work his professional knowledge and business sagacity helped the Secretary to save large sums of money for the Government.

McFarland, as a worker, is of essentially a healthy type,—buoyant, vigorous, and inspiring. He has, in marked degree, a faculty which is essential to men of affairs,—the power to preserve continuity of thought on any subject, under frequent interruption and deflection. While quick in decision and action, his judgment is exceptionally well-balanced and unerring. In closing this brief record, I can say only that I have written it with keen pleasure, in my pride in, and warm regard for, one of the ablest and most winning men with whom it has been my fortune to be associated.

* Some of the members of this board were Rear-Admiral Sampson, Captain Robley D. Evans, and Engineer-in-Chief Melville.—THE EDITOR.

PHOTO BY ALMAN & CO., NEW YORK

E. E. Olcott

PRESIDENT OF THE AMERICAN INSTITUTE OF MINING ENGINEERS

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CASSIER'S MAGAZINE

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THE SOCIAL ENGINEER

A NEW FACTOR IN INDUSTRIAL ENGINEERING

By Dr. W. H. Tolman.

IN the changed industrial and economic conditions of to-day the great concentration of capital and the massing of thousands of the employed have brought about new problems. In the old times, master and man lived and worked together,—there was a daily point of contact, a continuous personal touch. To-day all is changed. The employer, in many cases, is as much of an absentee as were the nobles in France in the latter part of the eighteenth century and the landlords of some of the worst tenements in slumdom. With the growing intelligence on the part of the workers, evidencing itself in a dissatisfaction with their social and economic surroundings, they are slowly learning how to crystallise their incoherent wants and their smothered discontents into definite propositions for an improvement of their conditions.

The personal touch between employer and employed has largely been lost, and it is not desirable, even if it were possible, to return to the earlier days. But for the successful conduct of the business of the twentieth century a point of contact must be sought for and established, though in a different way. This need has created a new profession, that of the "social engineer," a man who can tell the employer how he may establish such a point of contact between himself, his immediate staff, and the rank and file of his industrial army. Thus the writer was summoned in this capacity some time ago to advise a firm employing 2000 men and boys on the

A WORKMAN'S COTTAGE DOORWAY AT PORT SUNLIGHT, ENGLAND

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AN INDUSTRIAL COMMONWEALTH OF FIVE HUNDRED HOMES AT PORT SUNLIGHT, ENGLAND, CONNECTED WITH THE WORK OF MESSRS. LEVER BROS., LTD, SOAP MANUFACTURERS, OF BIRKENHEAD

subject of a building to serve as a social centre for their employees and also for the community where the factory was located.

On another occasion an employer of 5000 men asked me what form of industrial betterment he could begin. This led to a few questions on my part. First, were the men allowed to drink beer on the premises, especially at the noon hour. "Oh, no," was the answer; "we are very strict about that." Secondly, I inquired whether any rooms were provided in the factory where the men could eat their lunch, or any kind of a shelter outside to protect them from the hot sun of the summer. I found that nothing was provided. In summer they were obliged to eat their luncheon in the shadow of the buildings; frequently their heads were shaded while their bodies were exposed to the hot sun. Under these conditions it was not surprising that the men went to saloons where they could have their beer and the privileges of the free lunch counter in comparatively cool and comfortable rooms.

To change these conditions I advised the fitting-up of a room with plenty of windows and fresh air, and a temporary shelter in some part of the yard for summer use. I reinforced my suggestion by the instance of a certain factory where one large room is furnished with tables and benches. A kitchen is provided where plain, substantial food is furnished at cost price. The men are divided into sections and are given cards on which they write down their orders for the following day. One of their own number serves as waiter, going to the kitchen five minutes before the whistle blows to get the tray with the food which has already been placed there, corresponding to the written orders given on the cards. As soon as the men are seated at the tables, the food, smoking hot, is placed before them, so that there is not a moment's loss of time. The average price of a meal is 15 cents (7½d.).

After dinner they may adjourn to one end of the room where are tables filled with reading matter, trade papers, technical journals, magazines,—in fact, just the kind of reading matter that will appeal to the man at the bench who has a few minutes' leisure after eating. The men are also allowed to smoke for half an hour after they return to their work. The manufactured product is such as to permit this privilege in nearly all the rooms. There are very few factories

where smoking could be allowed, but the fact that it is allowed here shows that the employer is willing to do all in his power for the comfort of his men. My visit to this factory happened on a Friday, when a religious talk of seven minutes is given to the men after luncheon. The speaker gave the men a straight-from-the-shoulder gospel talk on the Prodigal Son. I watched carefully to see how many would stay for the talk. With the exception of about 20 men, who were reading, the remainder, 180, stayed for the address. When you consider that the men took their own time to listen to the religious talk, it is very significant. Since the establishment of this factory lunch room three saloons in the neighbourhood have gone out of business, and the fourth is having a hard time. In this particular factory the men appreciate the co-operation of their employer, and show it; however, in the majority of cases appreciation is not expressed, even if it be felt, but that fact does not lessen the obligation of doing one's duty. *Noblesse oblige* was never truer than to-day.

One of the first steps, in the writer's opinion, towards improving the condition of the employed is the provision of clean and comfortable rooms where men or women may eat their midday meal away from the noise, dirt, and routine of the work-bench or machine. The most far-sighted employers have been quick to see that taking care of their employees is good business, and have fitted up kitchens where a warm meal of plain, substantial food may be served at cost. The captains of industry are slowly learning a lesson from the captains of war, who lay great store on the physical equipment of their army, fully recognising that the best-fed and the best-nourished soldier is the most efficient one.

In a large paint factory it was found that a great deal of illness was caused by poor drinking water. This was a loss to the men, who could not work while disabled, and also to the firm, who lost the continuous service of good workmen. On making a study of the local conditions, it was ascertained that a service of filtration would overcome these evils, and accordingly a complete filtering installation was added to the

PORT SUNLIGHT COTTAGES. THREE SHILLINGS A WEEK

A CORNER ARRANGEMENT OF PORT SUNLIGHT COTTAGES

factory equipment at considerable expense, with the result that now typhoid cases are unknown there.

In the dry colour room in this same factory the workmen are provided with two sets of "jumpers," which they wear daily. At night the outer one is laundered. In the morning a clean one is put on next to the underclothing, while the inner "jumper" of the day before becomes the outer one of the next day. The lavatory is fitted up with spray baths, and each worker is obliged to use them, being given time of the company for this purpose. Those who wish may have their underclothing washed at the factory laundry. By the baths the pores of the skin are kept open, so that all impurities are worked out of the system. Formerly in this department a man lasted only five or six months; now lead poisoning is a thing of the past. The employee gains in having good health, and the firm do not lose time and experience in breaking in new workmen.

For the purpose of stimulating the employee to do his best, an increasing number of employers are offering cash awards for the best suggestions from their staff. In one large company a waggon driver called the proprietor's attention to the poorly paved streets about the freight stations, stating that he was never able to haul a full load of merchandise, to say nothing of the needless wear and tear on the horses and waggons. The attention of the city authorities was called to the poor paving, with the result that the streets are now in a proper condition. Thus the whole city gained by the suggestion made by one driver to an employer who had drawn him out by the offer of an award for suggestions.

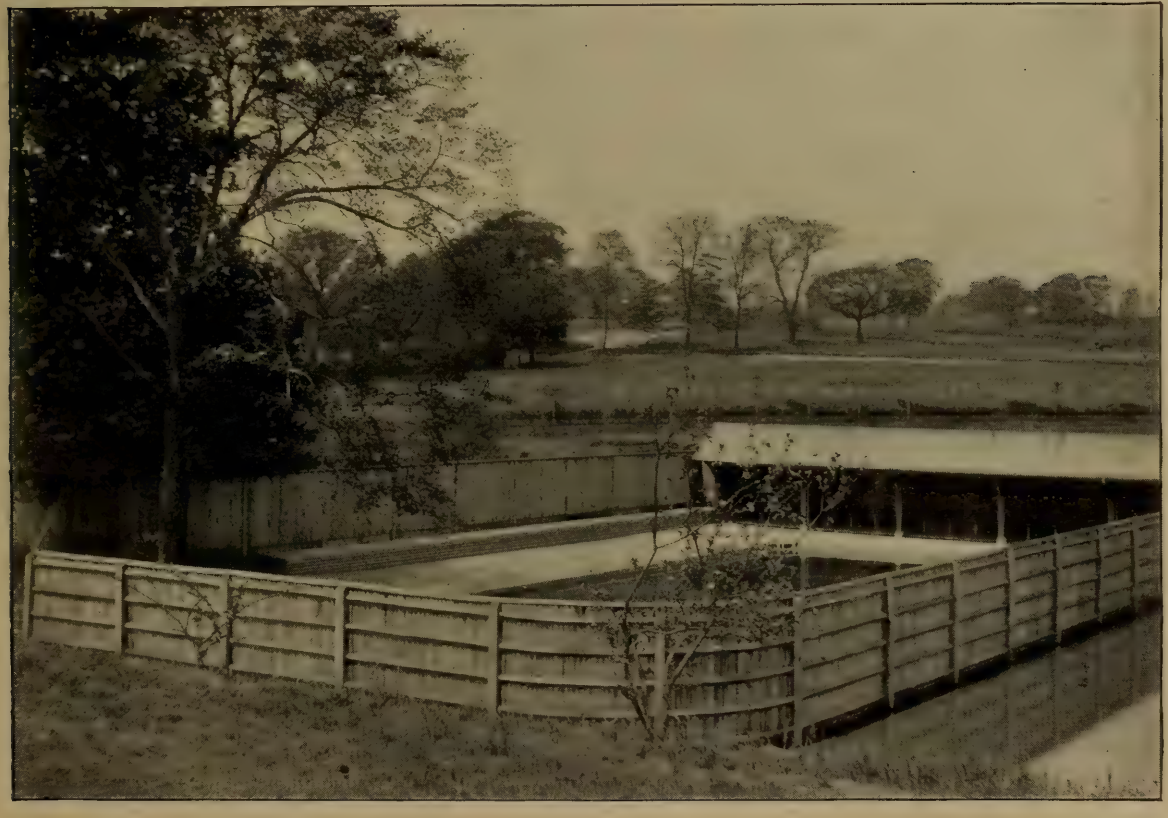
These are some typical conditions, and their betterment, which confront the social engineer. He must inform himself of all the various phenomena, while referring each manifestation to the underlying principles. In that way he accumulates a store of principles, with their applications, which will enable him to be of practical service when he is next called in consultation. In every case the local conditions and needs must be carefully studied so that the necessary adaptation may be made, for a brilliant success in one factory may be a dismal failure in another of the same

kind, without a study of the local environment.

The story of Port Sunlight, the industrial commonwealth built by Mr. William H. Lever for his 2500 employees at Birkenhead, just opposite Liverpool, is best told in some of the pictures, which accompany this article, of types of the five hundred cottages which make homes and gardens for the individual household possible. This village, with its opportunities for self-improvement, is the best illustration of what Mr. Lever so happily phrases, prosperity sharing.

In the great problems of railway transportation, there is the question of administration, the purchase of the raw material to be worked into the finished product by the company itself, and the actual operation of the railway itself. Some of the large lines are maintaining pension funds, libraries, and various movements for recreation. Take the New York Central Railroad by way of example! In the operation of the 10,453 miles of this system the services of an industrial army of 87,200 persons are required. Mr. Cornelius Vander-

WHERE THE PORT SUNLIGHT FIRM MEET EACH DAY FOR LUNCHEON



OPEN-AIR SWIMMING POOL AT THE WORKS OF MESSRS. CADBURY BROTHERS, LTD., COCOA MANUFACTURERS, BIRMINGHAM, ENGLAND. A MUCH APPRECIATED FORM OF INDUSTRIAL BETTERMENT WHERE THERE IS SUFFICIENT ROOM

A CORNER OF THE DINING ROOM AT THE BETHLEHEM STEEL COMPANY'S WORKS, AT SOUTH BETHLEHEM, PA., WHERE SUPERINTENDENTS, FOREMEN, AND CHIEF CLERKS "GET TOGETHER" DAILY AT NOON, FOR LUNCHEON SUPPLIED BY THE COMPANY

bilt had a building put up for the Railroad Branch of the Young Men's Christian Association to be used by the employees of the line. This was practically a railroad man's club, for there were then no "social secretaries" who were trained for the all-round management of such a club. This New York Railroad Man's Club is typical of the thirty-four others established along the line of this one road. On entering the building, it is almost impossible for the newcomer to escape the observation of one of the officials, who are there for the express purpose of serving the newcomer in any way. It may be that he is seeking information about the club and its organisation; if so, the necessary explanations are given, and he is made to feel at home. If he is a member, he has access to dining-rooms, sleeping-rooms, libraries, reading-rooms, gymnasiums, and baths; religious services, lectures and recreations. Provision is made not only for the temporal and mental, but also for the spiritual welfare of the employed.

The widening care of the road for the employee is further evidenced by a system of hospitals along the lines for the sick and injured. Travelling hospitals, as they may be called, are maintained,—that is, emergency boxes containing articles necessary for use in case of accident or injury, placed in cars, shops, and round-houses, the men receiving instructions in "First Aid to the Injured."

Closely allied to industrial betterment is social betterment, for every movement adding beauty, comfort, and satisfaction directly promotes a better communal feeling. In line with this thought, the engineering department of the same railway has established a system of horticultural gardens and greenhouses, from which plants and shrubs may be prepared for use at the various stations, and trailing vines are supplied for the purpose of covering up the bareness of fences, poles, and buildings, adding beauty by the subtraction of ugliness. This form of social betterment is not confined to the New York Central Company. It can be extended still further, for there seems to be no reason why the employees of the road should not be supplied with the vines, plants, and shrubs for their own home adornment, at cost, and, under certain conditions, free, provided that they would agree to plant and care for a definite amount. By that means each employee becomes a "missionary of beauty," bringing the delight and pleasure of the flowers not only to his own home, but to the community.

In preparing the programme for the great "Industrial Betterment" meeting which was held at New York a few months ago by what is known as the Get-Together Club, employers of 258,000 employed told what was being done to improve the conditions of their people, looking towards self-help and self-advancement. Mr. George H. Daniels, of the New York Central Railroad, in telling at this meeting why his road was doing all these things, said:—

"First, those responsible for the management of the New York Central lines, believing in the fatherhood of God and the brotherhood of man, realise that a sacred duty devolves upon them to aid, in so far as it lies in their power, their employees, who are associated with and more or less dependent upon them. They are, in a sense, 'of our household,' and it is our duty, as well as our pleasure, to assist them in living better, and, therefore, more useful lives.

"The second reason is a patriotic one. Those to whom is intrusted the management of these companies are impressed with their responsibility as citizens of this great republic, and are conscious of their duty to the State and national governments to set an example to their employees which shall be an incentive to them to become wiser and better citizens, and to enable them to perform those important services to the public that are a part of the duties of so many of the employees of transportation companies.

"The third reason is a business one. It is considered good business to surround our employees, so far as we possibly can, with healthful, helpful, homelike, temporal, as well as moral, influ-

ANZIN MINERS, THEIR FAMILIES, STREETS, AND HOUSES

ences. It is desirable, from a purely business standpoint, that every employee who is away from his home, on completing his work for the day or night, should have a regular resting-place which he can call his own, and where for a reasonable outlay he can secure a comfortable bed, good, wholesome meals, good papers and books to read, and good companionship. We consider that there is no excuse for such employees to be found in improper places or in questionable company.

"The employee who is surrounded by such helpful influences is ready at any moment to perform the duties devolving upon him in a manner which contributes to the safety and comfort of all who serve and are served by the railways. The construction by the New York Central lines of buildings such as I have briefly referred to, which will bring within the reach of their employees all those aids to correct living, the attainment of higher ideals of life, and help in the formation of sterling character, which is so essential in railway employees, will go on from year to year, until eventually at every division point there will be means provided, through the co-operation of the companies and their employees, for all these helpful agencies."

As a member of the International Jury in the section of Social Economy at the Paris Exposition, the writer had opportunity for studying what many of the great captains of industry are doing for the improvement of the conditions of the employed. In addition to visits to the industries in question, the opportunities for meeting the proprietor for the sake of getting his point of view found a valuable complement. For example, a meeting with M. Casimir-Perier revealed the fact that he, as the president of the board of managers of the mines of Anzin, in the north of France, was personally interested in industrial betterment. He asked many questions regarding American movements, and told me, among other things, that they were sending parties of 500 of their miners for a day at the Exposition, for a brief period of pleasure and profit at that great show. On learning that I

was desirous of visiting Anzin, he commended me to M. François, the director-general of the company, who, in turn, accorded me every facility for the study of their social institutions. I learned that the mines of Anzin were organised in 1716. At the present time the various concessions cover about 70,000 acres, or more than 10,000 square miles. In 1720, the first year the records were kept, the output of the mines was 55 tons; in 1899 it was 3,154,432. The yearly pay-roll for 1899 reached the sum of 18,182,432 francs.

In advising an employer what form of industrial betterment he will find the most important, I place a provision for a home, which, after all, is the true social centre. In the workshop, the worker is under discipline; his course of action is thought out for him, and he thus becomes a part of the system, a cog in an intelligent machine, so to speak. In his home, he is absolutely free; if the surroundings are such as to keep him in good health, to enable him to enjoy the charms of family life, he becomes a better man and a better citizen.

This great mining company possesses to-day 2884 cottages. At first the buildings were constructed in blocks, but on account of the disadvantages from the point of view of sanitation and morality, later structures were built in separate groups, in spite of the increased cost. Each house has a garden of at least eight square rods. One of the best forms of substitute for the evil side of the saloon is the small garden, offering healthful occupation, and, at the same time, remuneration, for the results mean a lessened expenditure for the food stuffs which otherwise would have to be bought.

SOME MORE MINERS' DWELLINGS AT ANZIN

With the idea of inducing each work-

man to save, the company built, at different periods, detached houses which it sold at cost price, to be paid for by monthly installments,—a little more expensive than the renting of a house of the same character in that neighbourhood. Ninety-three houses were sold altogether, having cost 275,000 francs. The company has also advanced money to its workmen for the purchase or the building of their houses in accordance with their own wishes. In this way 1,497,236 francs have been advanced, and the workmen have acquired for themselves 741 houses. Whatever helps the worker to increase his wage-earning capacity is a positive asset, because every employer is quick to recognise greater ability, and reward it by a position of greater responsibility.

The company has a school for boys in Thiers, a village occupied entirely by its employees. It has established day schools in two of the neighbouring communes, and three primary schools. In two localities it has founded, in addition, schools for domestic economy, where the instruction concerns the occupation of housekeeping, or homekeeping, for the knowledge of cooking, sewing, and oversight is a large factor in maintaining the integrity of the home. These schools are placed under the care of the Sisters of St. Vincent de Paul. The company also contributes towards the support of the communal schools which are patronised by a certain number of the employees. A special preparatory school, in which theoretical and practical courses are given by the engineers of the company, and which is destined to graduate skilled workmen, receives the best pupils who leave the primary school. The company, further, pays each year the tuition of several workmen at a mining school at Douai. Four churches, too, have been built by the company.

To help its employees save money, the company established, in 1869, a department for deposits, in which the workmen could make deposits up to 2000 francs, on which the interest allowed was at 3 per cent. The company no longer encouraged these deposits in its own department after the creation of

ONE OF THE NINETEEN CO-OPERATIVE STORES, MANAGED ENTIRELY BY THE OPERATIVES IN THE MINES OF ANZIN

the postal savings banks, since these give the workers every facility and every guarantee for banking their savings. At present the company's bank has only 184 depositors, as opposed to 1431 in 1877.

A co-operative society was founded in 1865 on the initiative of the company. In addition to food stuffs of all kinds which are bought in bulk, this society has its own bakeries, dairies, butcher shops, and wine cellars. All sorts of household utensils, clothing, and, in fact, all articles for which a demand exists, are supplied. The company itself buys from the co-operative stores soap, brushes, pails, and other small supplies for factory and office use. The society has its own chemists, who analyse all the food stuffs and test the merchandise, so that the members are protected in having the purest supplies and standard products at the lowest market rates. To-day the stores are absolutely independent, with nineteen branch establishments and a force of nearly 100 of its own employees. The present number of co-operators is 5642. The sales in 1899 reached 3,934,611 francs, with a net profit of 744,471 francs to be divided among the co operators.

A superintendent of a large business told the writer that they used up a man about every six years; then they had to get others, and so the process went on. Employers are recognising that they owe these used-up men and their families a moral obligation that is met in the most satisfactory way by payment in the coin of the realm, that is, a substantiality that will be accepted by the butcher and the grocer. Until 1886 the Anzin company accorded pensions to its retired workmen without making any charge upon their salaries; but since 1887 it has, like the National Bank of Pensions for Old Age, deposited in the name of the workmen a sum representing 1½ per cent. of their salaries. The law of 1894, whose regulation the company had anticipated, imposed on the employer, as well as the workmen, a deposit of 2 per cent. of the salaries. These two sums are inscribed on an individual pass-book, which is then the property of the workman, and as soon as he becomes fifty-five years of age he may receive, in liquidation, an annual pension in accordance with the French law.

In addition to participation in the pension system, the company, of its

AN ANZIN MINER

own accord, since 1887 have given to those of its workers who have remained in its service until they are fifty-five years of age, an additional pension of three francs a year for their services, calculated from the time when they fulfilled the double condition of having been at least thirty-five years of age and having worked for the company ten successive years. This increase for long service is doubled in favour of married employees living with their wives. In case of severe accidents or injuries contracted while at work, the pension can be realised in advance. It includes the pension on the part of the Bank for Old Age, the pension for long service, and an allowance by the company which may reach 180 francs a year. The pension of the widows of workmen killed outright or having died in consequence of wounds received while at work, includes the pension in liquidation from

A RESCUE PARTY OF MINERS AT ANZIN

GARDEN PLOTS CONNECTED WITH THE MINERS' COTTAGES

the Bank of Old Age, premium for long service, and an allowance of 180 francs, to which is usually added an annual benefit fund of the same amount. Temporary aid is given to orphans until they are old enough to begin work. Parents of workmen killed outright or in consequence of wounds received while at work, receive a pension of 180 francs a year, if the workman has been considered as the support of the family.

Closely allied to institutions for the promotion of thrift are those which enable the workmen to be free from economic care and worry during actual or potential sickness. At Anzin a medical service is maintained by thirteen physicians, of whom six are chiefs and seven assistants each having a certain district. They give their care gratuitously to the sick and wounded workmen, as well as to their families. Each physician has in the centre of his district an office for consultation, where at certain hours every day he receives the sick and injured who can come. The others are visited at their homes. The workers receive gratuitously medicine, money aid (when needed), wine, meat, and soup. In 1892 the board of managers of the mines decided that a sum equal to the dividend of one-half denier* should be allowed as a kind of subsidy to the mutual aid societies. Accordingly, from this source, in 1899, the sum total of 11,000 francs was realised by these societies. From a statement that was sent with the company's exhibit to the Paris Exposition, the following cost to the company of their industrial betterment institutions has been summarised:—

	Francs.
Instruction	26,583
Estimated loss on the houses and the foregoing of interest on the money advanced	321,543
Annual aid	72,006
Assistance for the sick, wounded and various allowances	152,674
Department of Hygiene	143,917
Estimated value of the coal distributed	443,711
Pensions	441,799
Expenses of the Pension Fund	321,487
Fund for the increase of pension for long service	100,000
Pension paid to superintendents, employees and their widows	320,695
Expenses for the Nat'l Bank of Pensions	24,000
Formation of capital sum for premium for long service for heads of departments and employees	120,000
	2,488,415

* A denier is equivalent to about one-twentieth of a penny in English money.

Among the leaders of industrial betterment in Holland are J. C. Van Marken and his wife, each of whom is equally identified with the various movements for improving the condition of the employed in their works, where nearly 1200 people are engaged in the manufacture of yeast and spirits. The writer had the pleasure of meeting the Van Markens at Paris, and also enjoyed

"The Factory for all:
All for the Factory."

THE VAN MARKEN FACTORY BANNER, CARRIED ON STATE OCCASIONS EACH DEPARTMENT HAS A SYMBOLIC BANNER

their hospitality while studying their factory at Delft. The idea of the social engineer was no new one to Mr. Van Marken. Very early in the industrial history of this plant Mr. Van Marken felt the necessity for providing homes for the employees, clearly recognising that this step was of the first importance

THE RECREATION ROOM OF THE NEW YORK CENTRAL RAILROAD MEN'S CLUB

in any plan for industrial betterment. Adjoining the factory was a low-lying tract of land which Mr. Van Marken had drained, and this is now one of the garden spots of Holland, being called Agneta Park, in honour of Mrs. Van Marken. The park is a fine tract of ten acres, near the town of Delft, with lakes, trees, lawns, and houses. Mr. Van Marken's own home is in the park, which has thus become the centre of the social and intellectual life of the workers in the several factories.

THE HOPE OF THE FUTURE AT AGNETA PARK

The oldest and most important of the works is the Netherlands Yeast and Spirit Manufactory, founded by Mr. Van Marken in 1870 with thirty employees,—now the largest yeast factory in the world. Boards of directors in our industrial establishments do not contain representatives of the workers, but for the sake of the promotion of a good understanding between capital, management, and labour, a representative committee might be formed. Such a body is organised at Delft, and is called the "Kernel," which may be considered a labour parliament, composed of three chambers:—

(a) The Chamber of Managers, to which all the managers and upper clerks, chief engineers, etc., belong, twelve in number. Quarterly meetings.

(b) The Chamber of Masters and

Clerks. This comprises the two eldest in service and six other masters or clerks, elected by their equals in rank. Monthly meetings.

(c) The Chamber of Labour. Members,—the four oldest in service under the rank of master or clerk, and twelve elected by their fellow workmen. Meetings twice a month. Members of this chamber receive twenty-six florins a year as compensation for loss of working time.

Elected members sit for two years, half retiring each year. The elections are by ballot, and are held in the month of January. Each chamber chooses its own president and secretary, the latter of whom is paid 100 florins a year for his services. The whole "kernel," that is, the three united chambers, meets in open sessions on the first Tuesdays of March and September.

These various chambers meet to discuss matters relating to their various constituents, the common interests, etc., of the factory. At the meetings of the combined chambers, each chamber may give notice of motions, etc., and in all questions affecting only the interests of the employees the decision of this committee is final. In those questions which affect the interest also of shareholders or management, the resolutions of the "kernel" have only an advisory or consultative character. The "kernel" was originally instituted in 1875, but then consisted of one chamber only, embracing the engineers and higher clerks, clerks and masters. This body was summoned, when thought necessary, by either the directorate or the workmen. But it was found to be unwieldy for effective deliberation, and the presence of their superiors had the effect of silencing many of the workmen's representatives, and in 1891 the changed organisation referred to above of three chambers was, therefore, made.

This institution has led to no friction between employers and employed, but it has awakened much interest among both, and the proceedings of the Chamber of Labour are followed with great keenness. There is the department for the interests of the employees, instituted in 1880 primarily to direct the various friendly and charitable institutions connected with the factory, and to provide a place where every member of the staff could seek advice as to his personal surroundings and wants. With the growth of the factory it was found necessary to furnish direction for the various friendly and charitable institutions connected with it. This was secured through what is known as the United Committee, composed of four departments, viz., intellectual development, recreation, furtherance of material interests, and finance. The executive head of the committee is known as the

TEN CENTS A NIGHT. WHERE THE TIRED TRAIN MAN MAY REST

THE NEW YORK CENTRAL RAILROAD MEN'S CLUB. DINING AT COST

director, who is responsible to the firm for the management of the committee. Each of the four departments is managed by a committee of three, two nominated by the "kernel" and one by the directorate. Each department appoints sub-committees, who, in turn, are responsible for that part of the work coming directly within their scope. For example, the educational department has twelve sub-committees:—1, kindergarten; 2, school attendance; 3, domestic economy and feminine handiwork; 4, industry in the home; 5, theoretical education of apprentices; 6, practical education of apprentices; 7 and 8, theoretical and practical education of clerks; 9, instruction in the technical science of the factory; 10, science classes and lectures; 11, library and reading-room; and 12, the *Factory Messenger*, a weekly factory paper.

The aims of this united committee are three,—first, to promote the development and interests of these institutions, which have been or shall be founded or subsidised by the directorate; second, the supervision and control of these institutions; and third, the promotion and sustension of a union of these institutions with one another, and also with such institutions which, founded by the staff independently of the directorate, may be desirous of entering into this union.

There are two savings banks, the one voluntary, the other obligatory, for a part of the premiums and of the share in profits. From the latter deposits may be withdrawn in case of marriage up to an amount equal to a half-year's wages; on the birth of a child, two weeks' wages; for private insurance, buying of a house, etc.

In sickness, full wages are paid during eight weeks. If the workman's illness lasts longer than that time the committee for the "Interests of the Employees," which is supplied with the necessary funds by the factories, takes him on its funds. In case of accident, full wages are paid until recovery. There is also an insurance, yielding two years' wages in case of complete inability or

death. The yeast company pays 9 per cent. every year of the total amount of wages to an insurance company. This constitutes for every individual an annual income for every year's service, to be paid from the sixtieth year of age. Forty annual payments (service from the twentieth until the sixtieth year) constitute an amount equalling the average annual salary received during the whole time of service. In case of death before the age of sixty, the widow or children receive 9 per cent. of the total amount of wages earned by the deceased during his whole service. Pensions have been insured also for the workmen in the oil works and printing office.

There is a direct relation between capital, labour, and management, the three essential elements necessary to every enterprise. Consider how useless is capital without management to direct its resources, and, in turn, how both capital and management are dependent on the willing hands of labour to execute their will. Capital should conscientiously do all in its power to improve the condition of the workers, for a more vigorous man is able to do more work, a more intelligent man will do better work, and a more conscientious man will do more faithful work. On the other hand, labour should not view with cold suspicion the overtures of capital, but should meet them in a friendly spirit, with a mind open and ready to co-operate. Many employers have found that their efforts for industrial betterment have been met with surly looks, suspicion, and indifference.

But it is not fair to expect the employer to do all. The capitalist should not be regarded as a thief and a robber; labour should recognise the sincerity of his motives, and give him a chance to prove his sincerity by working with, and not against, him.

THE TRAINING OF WORKMEN

THE EFFECT OF MODERN INDUSTRIAL CONDITIONS

By Joseph Horner

IN the much-agitated discussions of the proper training of workmen there has been evidence frequently of lack of knowledge on the part of many who are supposed to know as to how the modern factory is supplied with labour and how machine developments have, in many instances, killed the craftsman, while in many others the value of handicraft has been lessened.

If the conditions of labour were unchanging, then the apprenticeship system of the mediæval ages could be revived with advantage to-day. But a new industrial order is occupying the place of that which has passed. Trades must now be classified according to the degree in which either hand work or machine production predominates, and the training which is best adapted for one class is not suitable for the other.

The usual practice in factories where machinery is the dominant factor is to bring in lads or girls to mind the simpler machines first, and pass them on from the lower to the more complex, as they grow older. Two or three days suffice to learn the handling of many simple machines; dexterity may be acquired in two or three weeks. Then by the time those little workers reach adult age they find themselves thrown out, to make room for relays of cheaper boy or girl labour.

In many shops and factories you may see whole departments occupied thus mostly by youths or girls under age, but in charge of a few hands,—staid men or women of twenty-five or thirty-five. The young, precocious toilers are not learning a trade that will serve them for life,—they are merely earning wages. To this class belongs the largest proportion of young people in the spinning mills, in stay-making factories, in jam, pickle and match, and cocoa factories, in clothiers', and in boot and shoemakers' establishments For these, apprenticeship would not be of the slightest value.

Outside this group, again, is the immense army of casual labourers, of men and women who are ready to do any job that turns up, where brute force and a minimum of intelligence are the only equipments required. This immense army, which does the rough, repugnant work of the country, is untouched by schemes of apprenticeship or education. Many of them may be old factory hands, discharged to make room for the children whom they have reared. Even so, their children, in turn, will face that future. After twenty, twenty-five, thirty years of age, they will do as their parents have done, and get such casual jobs of work as they may.

In the trades where handicraft still retains a place we are met with facts which tend to lessen the value of apprenticeship, though they may not yet supersede the practice. For in truth it is hard to say how long skilled craftsmen will be required, even in those trades where they are still in demand. It is, therefore, impossible to consider the question of apprenticeship to those trades, except as a necessity of a temporary character.

The writer was fortunate enough to be apprenticed at a time when there was still a chance of gathering a good, all-round knowledge of engineering. But since that time each department has been sharply divided from the others, and machinery has deeply invaded every one to an extent entirely undreamed of

in the days of his youth. A corresponding change has come over the methods of training adopted. At that time nearly everyone in every department was regularly indentured. Now the practice has been abandoned in the great majority of engineering factories. Lads come in, and pick up their knowledge in a hap-hazard way. Often there is either a verbal or a tacit understanding,—which becomes a point of honour,—that a lad shall spend a certain number of years with the firm, in return for the opportunities afforded him of learning how to work; but there is no indenture. This is the general usage now in British shops.

So, too, in other trades, indentured apprenticeship, or its equivalent of a period of service, is still adopted. In boiler making, shipbuilding,—to a lesser extent in smiths' work,—in cabinet making, carpentry and joinery, masons' work, plumbing, metal plate working, tinmen's and copper smiths' work, and in a good many other trades in which a greater or less degree of manual skill is required, these are the systems in use.

These statements, of course, are made on the strength of the writer's own observations. I am not aware that any statistics bearing thereon are available. With regard to the United States, four years ago one of the engineering periodicals sent out letters of inquiry to two hundred of the leading machinery establishments in the country, asking their experience of the apprenticeship system. One hundred and sixteen establishments replied; eighty-five of these took apprentices, and only 47 per cent had any written agreement. In America, therefore, lads come into the shops and just find their vocation and their level at the tasks at which they become most adept. They will, in many cases, settle down into specialists, but they do not begin as such.

In some highly specialised industries, as in the making of type-writers, cash registers, astronomical and optical instruments, chronometers, and such like, the men are often trained from boyhood in, and remain the specialists of, one firm only. In such cases the apprenticeship system is distinctly advantageous. But these high-graded industries form but a small proportion of the whole, and an argument of universal application cannot be deduced from their usages.

Nearly all trades and handicrafts have been invaded by machinery, some in a vastly greater degree than others. Work which was deemed beyond the capacity of machines but a few years since is now regularly done by them. A modern steam boiler is, in every detail of its construction, a machine-made article. From the shaping and bending of the plates to the fastening of the rivets and the tightening of the joints, machine work is paramount. The riveting of ships' hulls otherwise than by hand, deemed impossible a few years ago, is now done by portable squeezers, operated by water, or by compressed air. The old iron founders laughed at the idea of ramming moulding sand around patterns by machine. It is done now in America, in Germany, and, to a slight extent, in Great Britain.

When machine-made panel doors and sashes are made or imported into Great Britain, the carpenter and joiner know that innovation will not stop here. The trade of the British cabinetmaker is invaded by American machine-made goods. And the cabinetmaker of to-day, even where hand work predominates, is not like his father. He makes a table top, but not the legs. The man who makes the legs cannot make a wardrobe. The wardrobe hand never touches a chest of drawers, or a sideboard, or a chiffonnier. Another man makes chairs only; but, if they are carved, that work is relegated to someone else.

Take the sartorial craft, or boot and shoemaking, or watch and clock-making. The salesmen who deal with the product behind the counter are not craftsmen, neither are the workpeople who make them in the factories. The best craftsmen to-day in these and other industries are those who execute repairs!

And so we might run through many

other occupations, where men no longer exercise a craft as a whole, but only a very small part of that craft. Men are now subservient to machines; gone forever is that devotion to labour which the old craftsmen enjoyed, and which has left its impress in Gothic arch and poems in stone; in mediæval brasses, and Chippendale furniture; in cameos, and pottery; in craft wedded to art; in *chefs d'œuvre*, which are the wonder and despair of the present. These facts are enough to discount the value of a long apprenticeship now. But more remains to be said.

Apprenticeship under the old guilds was an intensely personal relation. But the relations between employers and factory hands to-day are impersonal. An apprentice now is only so in name, a numbered unit who puts in his cheque with other numbers. He is not taught a trade. He must pick it up for himself. It is nobody's business to instruct him, neither his master's, nor his foreman's, nor the workmen's. In some of the smaller shops in country towns traces of the old relations still remain, but they are becoming more and more exceptional.

And yet more remains. It is generally to the interest of an employer that an apprentice should not learn his trade as a whole, but only a little section of it. It pays better to keep a lad repeating the performance of one section of his craft than to teach him all. More money is made. But the apprentice becomes a young specialist, a prig in his teens, cocksure over some little piece of handicraft, at which he may earn something over his normal wages. And many a lad does not become disillusioned until he has to face the world and try his luck in other shops. And, therefore, the best shops in which to place a lad are not the big establishments, but the small ones, where every class of work is done, and where tools and appliances are often scant. A lad will learn more in these than in those replete with every appliance, and minutely sub-divided into sections and groups.

The best training for a lad to-day is that which he can evolve for himself. The greatest evil that can befall him is to become a specialist, and nothing more, while in his teens. Yet that is what must happen if he spends several years tending machines, or doing repetitive, unvarying tasks in one big establishment.

The best training, therefore, to-day is that gathered by the peripatetic youth. If a lad cannot gain experience in one place he should move about, gathering as much as he can accumulate with one firm, then on to another, and attending training schools as opportunity offers. His views become broadened, he becomes self-reliant, and, in time, having found his true work, he may settle down as a specialist.

These views will come as a shock to many. But I can arrive at no other conclusion. And those who know me will at least admit that I write from the fullest knowledge of factory life, and of industrial needs and conditions, knowledge gathered during many years of practical duties.

AERIAL NAVIGATION

BALLOONS AND FLYING MACHINES FROM AN ENGINEERING STANDPOINT

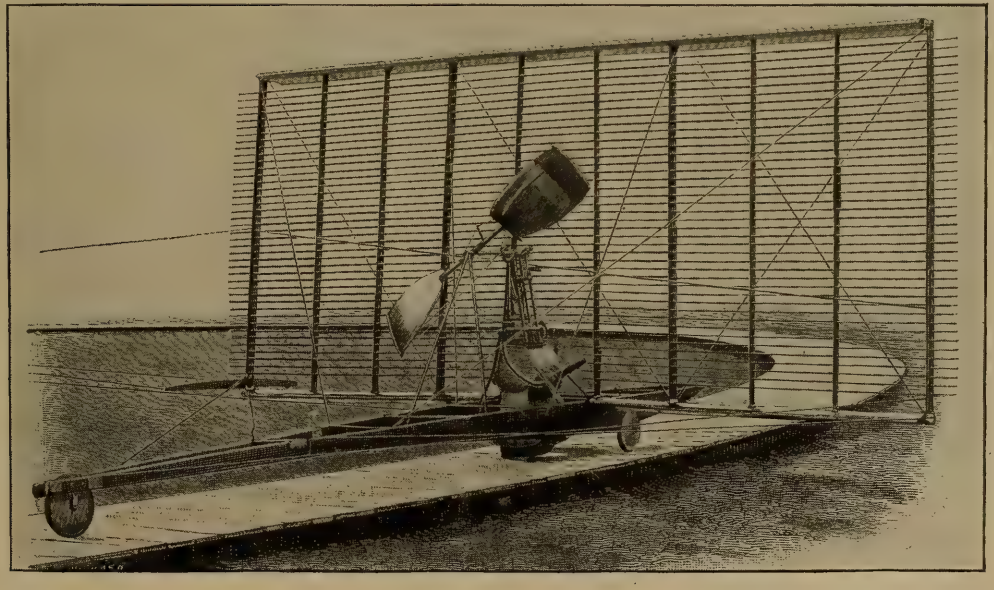
By Octave Chanute

BALLOONS

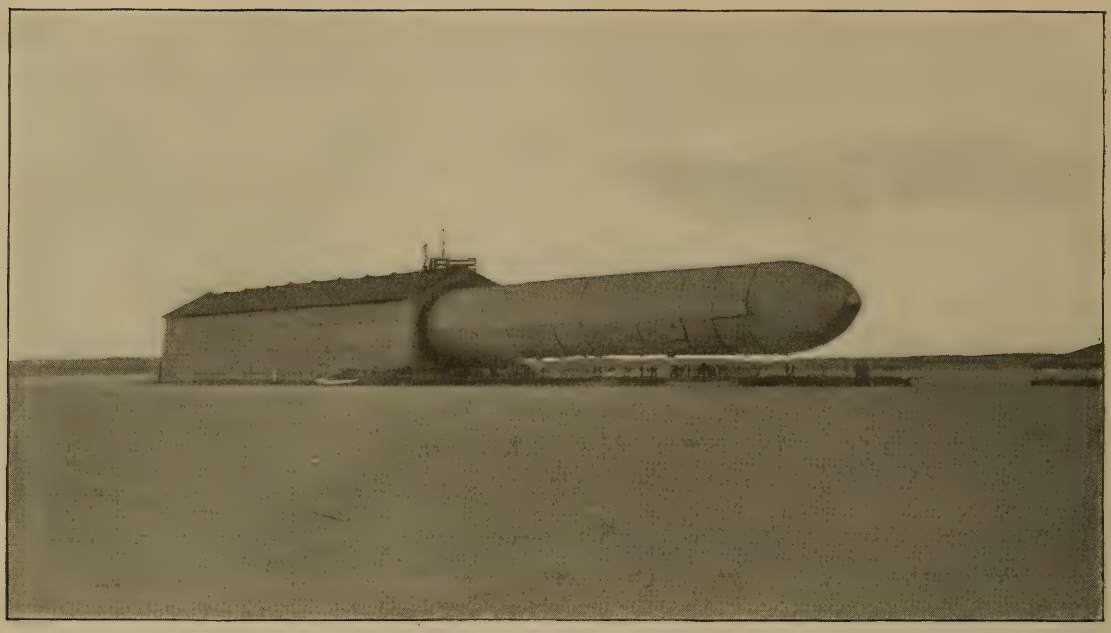
RENEWED attention has recently been called to the problem of aerial navigation, in large part by the experiments of Count Zeppelin, who is said by some of his admirers to have devised a final solution. While this claim cannot be allowed, it must be admitted that he has achieved a notable advance upon the performances of his predecessors, and the present time seems fitting for a discussion of the subject of both balloons and flying machines from an engineering standpoint.

The balloon problem is chiefly that of imparting to the vessel a sufficient speed to stem the winds that blow. A balloon of given size has a certain lifting power, and no more. It has to carry up its own weight and that of its adjuncts and crew, so that only a certain number of pounds can be spared to cover the weight of the machinery and its supplies. The horse-power available within that weight determines the possible speed, and this is small indeed, for the resistance grows as the square, and the horse-power required as the cube, of the speed. In the three trial trips which Count Zeppelin's balloon has made it seems to have attained a speed of 18 miles an hour; this is somewhat more than has been achieved before, but it is not enough for regular, everyday use.

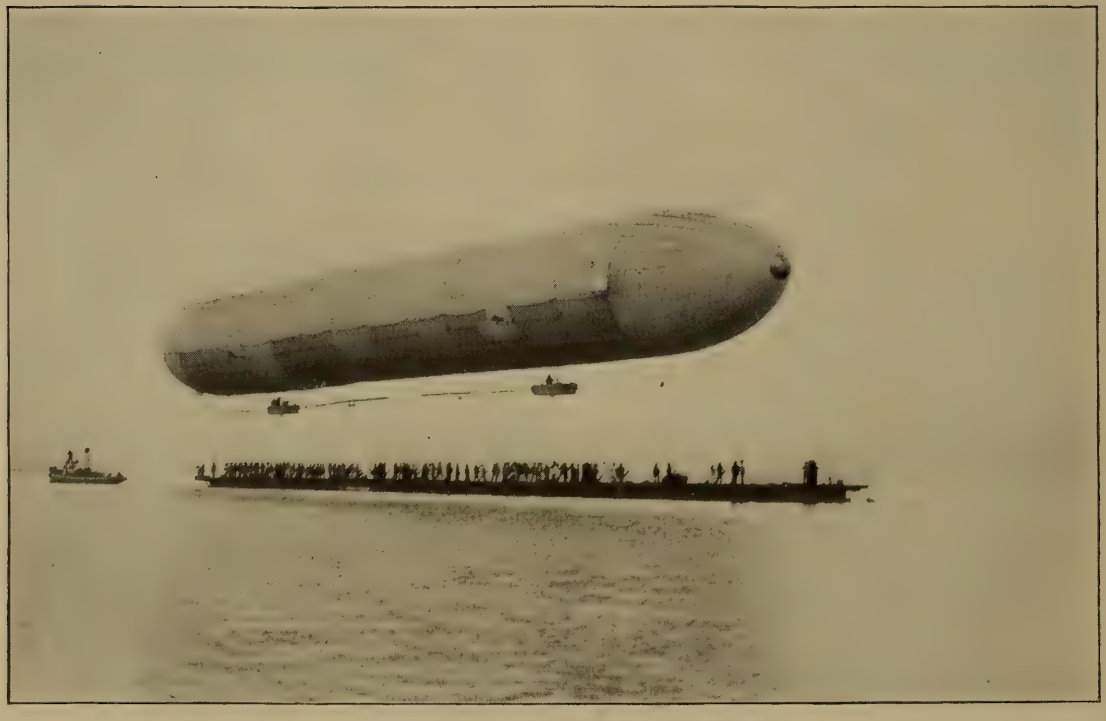
The evolution of fusiform balloons began in 1852, when Giffard ascended in one 144 feet long (provided with a steam-engine of 3 horse-power, which weighed 462 pounds), and attained a specific, or independent, speed of 6.71 miles per hour. In 1872 Dupuy de Lôme went up in a balloon 118 feet long, and attained 6.26 miles an hour with man power. In 1884 Tissandier



PHILLIPS' FLYING MACHINE



TO HOUSE THE BALLOON A BOATHOUSE AND PONTOONS WERE PROVIDED



COUNT ZEPPELIN'S BALLOON

attained 7.82 miles an hour in a balloon 92 feet long, with an electric motor of 1.5 horse-power weighing 616 pounds, while Renard and Krebs, in 1885, increased the speed to 14 miles an hour in the balloon *La France*, 165 feet long, provided with an electric motor of 9 horse-power, weighing 1174 pounds. These are large vessels, there being many coasting steamers smaller than the above-mentioned balloons. In 1897 Schwarz is said to have attained, for an instant, 17 miles an hour with a balloon 157 feet long and a benzine motor of 16 horse power, but his apparatus came to grief immediately thereafter; and now Zeppelin has reached 18 miles an hour with a balloon 420 feet long and

39 feet in diameter, provided with two benzine motors of 32 aggregate horse-power, weighing 1430 pounds.

In each case the power of the motor was the maximum available with the surplus lifting power at command, but the shape also influenced the speed. Count Zeppelin would have performed still better if he had imitated the fusi-form shape of the French balloon of 1885. The resistance of this was given by Renard as $R = 0.01685\ D^2 V^2$ in metric units, and amounts to $R = 0.0006876\ D^2 V^2$ in British units, in which D is the diameter of the balloon in feet; V the speed in miles per hour; and R the resulting resistance in pounds. This amounts to 18 per cent. of that of a thin plane equal to the larg-est cross-section in area.

Zeppelin having obtained a speed of 18 miles an hour, as stated by himself, the resistance of his ship is

$$\frac{32 \text{ H. P.} \times 375}{18} = 667 \text{ pounds},$$

which is 34 per cent. of that of a disc thirty-nine feet in diameter with a pres-sure of 1.62 pounds to the square foot, this pressure being that due to the speed. The equation for his air ship is, therefore, $R = 0.001353\ D^2 V^2$ in British units, but he might have at-tained about 22 miles an hour had his shape been the same as that of Renard, and still more had it been that of a fish, say, a salmon. He, therefore, acted wisely in discontinuing his trial trips and in selling his present balloon to the German Government, as reported at the time by newspapers.

Quite a number of novelties have been introduced in Count Zeppelin's construction, some of which will prob-ably be permanently adopted in future balloons. They may be epitomised as follows:—

1st. Instead of depending upon the internal pressure of the gas to preserve the shape, he adopted a rigid skeleton frame of trellis work. This, doubtless, adds greatly to the weight, and, there-fore, to the required size; but it adds also to security.

2d. Having, thus, a rigid framework, the propellers are located on the balloon itself. They are, therefore, nearer the centre of resistance and more effective than if attached to the car. It is prob-able, on the other hand, that in this case they were made too small.

3d. The whole body is sub-divided into seventeen separate balloons, thus greatly reducing the danger of accident by the escape or motion of the gas.

4th. An outer cover or casing is pro-vided around the balloon proper, thus leaving an air space and reducing the variations in lifting power from alterna-tions of sunshine and from changes in outside temperature.

5th. The angle of incidence of the apparatus is changed by a sliding weight, thus facilitating ascent or de-scent.

6th. With ingenious precautions a benzine motor is employed, and hence fuel can be provided for ten hours. Any fire in proximity to hydrogen has hith-erto been deemed so hazardous that only Giffard, Schwarz, and Wölfert had

ADER'S FLYING MACHINE

LILIENTHAL'S DOUBLE-DECKER

dared to use it, and the last was killed in the attempt.

7th. To house the balloon a boat-house and a set of pontoons were provided. This worked well, and seems preferable to sheltering such a fragile body on dry land.

8th. A lake was chosen on which to experiment and alight. The cars were, therefore, shaped like boats. They had double skins, filled with water, and this may prove safer and more convenient than sand ballast.

It may, therefore, be said that the safety and usefulness of war balloons have been increased by Count Zeppelin, and that a speed of about 25 miles an hour is possible with his apparatus. This may, doubtless, serve on occasion, but there will be many days when the wind aloft will blow faster than this speed.

Meanwhile, M. Santos-Dumont has been experimenting in Paris with moderate-sized balloons propelled by gasoline engines. He has built four of them successively, the last being provided with a 7 H. P. motor. With this he means to try for the "Deutsch prize" of $20,000, offered through the Aero Club last year, which offer is open to any aerial apparatus which, starting from the grounds of the club, shall, within half an hour, proceed to the Eiffel Tower, circle around it, and return to the starting point, an aggregate distance of 6.83 miles, therefore requiring a speed of about 14 miles an hour. This offer is to continue for five years, unless the prize is won sooner.

But while the problem of dirigible balloons is pretty well evolved, and while they may serve in war and in exploration, there is small hope that they will serve commercially. They possess the advantage of providing independent flotation, but they have inherent defects. They are comparatively slow, they are very frail, and they are very costly. Only governments can afford to employ them.

While balloons, therefore, will probably constitute one solution of the problem of aerial navigation, there is also another solution, that of flying machines, which promises much greater

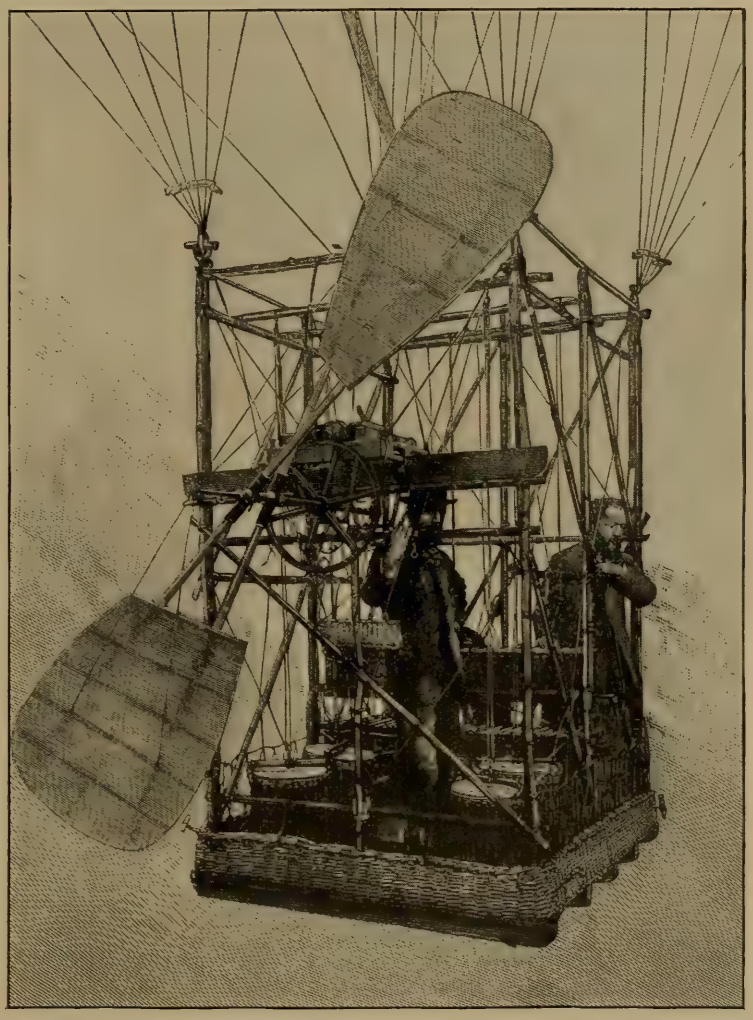
speeds, although their commercial use will likewise be limited. The principles and computations pertaining to dirigible balloons are now fairly well understood. It is clear that the size must be great, even to the verge of impracticability, the form must be that of least resistance,* and the length should not be more than ten times the diameter in order to insure stability. Moreover, the propeller must be effective and preferably at the front, and the motor, including its supplies, should develop great power in proportion to its weight. If all these conditions be observed, the French experts allow that the ultimate speed may attain 44 miles an hour in the distant future. This is about the speed with which motor-driven flying machines will begin.

FLYING MACHINES

Some imaginative investigators have, therefore, resumed the search, antedating by far the invention of the balloon, for the conditions to be observed in devising a practical flying machine in imitation of the birds. Much of past work has been fanciful and crude, but there are now aeronautical societies and technical publications in most countries which promote sound research for both balloons and flying machines, and an international congress on these subjects was held at Paris in September, 1900. This congress had an elaborate programme for papers and discussions. Only abstracts of the proceedings have been published at this time of writing, but as no great advance or discovery was announced, this paper will not be incomplete if it merely recapitulates what was already known.

* This may, perhaps, be brought down to 12 per cent. of that of a disc equal to the maximum cross section.

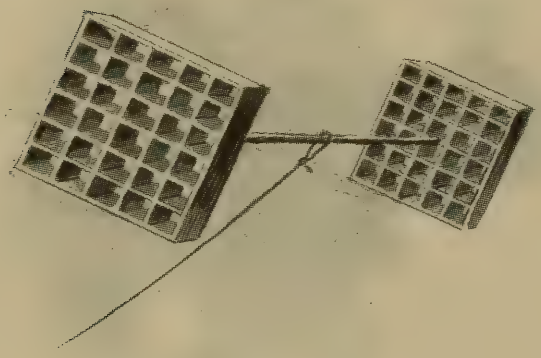
Attempts at artificial flight date back to the very dawn of history, but such attempts have been impeded by two main obstacles so prohibitive as at times to cause the investigation to be classed with that into the possibility of perpetual motion. These main obstacles are, first, the extreme danger in man's attempts to acquire the art of the birds, or to fly with an apparatus as yet imperfect; and second, the lack of an artificial motor as light, in proportion to the power developed, as bird machinery. We know, approximately, that the motor muscles of birds develop such an output of energy that a full horse-power, if such were produced, would weigh but from six to twenty pounds, while our most powerful locomotives, with their tenders, weigh about



THE TISSANDIER BALLOON, 1883. THE PROPELLER WAS DRIVEN BY CURRENT FROM BICHROMATE OF POTASSIUM BATTERIES

two hundred pounds to the horse-power. This great gap has been partly closed within the last ten years, and investigators into flying devices are no longer regarded as visionaries.

It was about 1889 that a number of



HARGRAVE'S KITE

competent men simultaneously, but independently, took up the problem Apparently the times were ripe, and already the advance since then has been greater than during the preceding three centuries. Langley, in the United States, and Maxim, in Great Britain, had become convinced that the current coefficients used for oblique air reactions were incorrect, and began experiments of their own to ascertain the facts. They both selected plane surfaces for trial, and reached much the same results as to the lifting power and resistance which are to be obtained from the air at various angles of inclination and at various speeds. These proved to be many times greater than those given by the ancient formulæ, and these experimenters determined upon building actual flying apparatus which should be driven by power.

Aside from the general design and the form and arrangement of the supporting surfaces, the important elements to consider are the ratio of those surfaces to the weight and the comparative power and speed required. There has been considerable range in these elements in the various experiments, and these will be described so as to bring out the important points. Langley began producing working models of flying machines in 1891. He tested various arrangements of wings and of surfaces, and successively applied steam, gasoline, and carbonic acid gas motors, and then steam again, struggling also with various methods of launching the apparatus into the air. At last, in May, 1896, one of his machines made two flights of about half a mile each in about one minute and a half, and later, in November, another machine flew once, more than three quarters of a mile. The whole apparatus weighed 30 pounds and spread 70 square feet of supporting surface, or in the ratio of 2⅓ square feet to the pound. The steam-engine was of 1 horse-power and weighed 7 pounds, thus sustaining in flight 30 pounds per horse-power, but running down very soon because the water in the boiler was exhausted.

Maxim began on a much larger scale. He undertook the construction of a full-sized flying machine to carry three men, spreading 4000 square feet of supporting surface, and weighing 8000 pounds, thus affording only half a square foot to the pound. It was provided with a compound steam-engine and a boiler of 363 H. P., a marvel of ingenuity and mechanical skill. This apparatus was provided with wheels, and was placed upon a railway of 8 feet gauge, being restrained from premature flight by a pair of outside wooden rails placed above the wheels. Many experiments were made to test the speed required and the lifting effect, during which various mishaps were encountered and repaired. After several years of this study, the machine, in 1894, unexpectedly undertook free flight, by bursting through the upper rails during one of the tests. It flew, perhaps, 300 feet, but steam was at once shut off, and the apparatus alighted and was broken. The damage was repaired, but as the machine sustained only about 28 pounds per horse-power, requiring a speed of 36 miles an hour, and as it had been very costly and other business pressed,

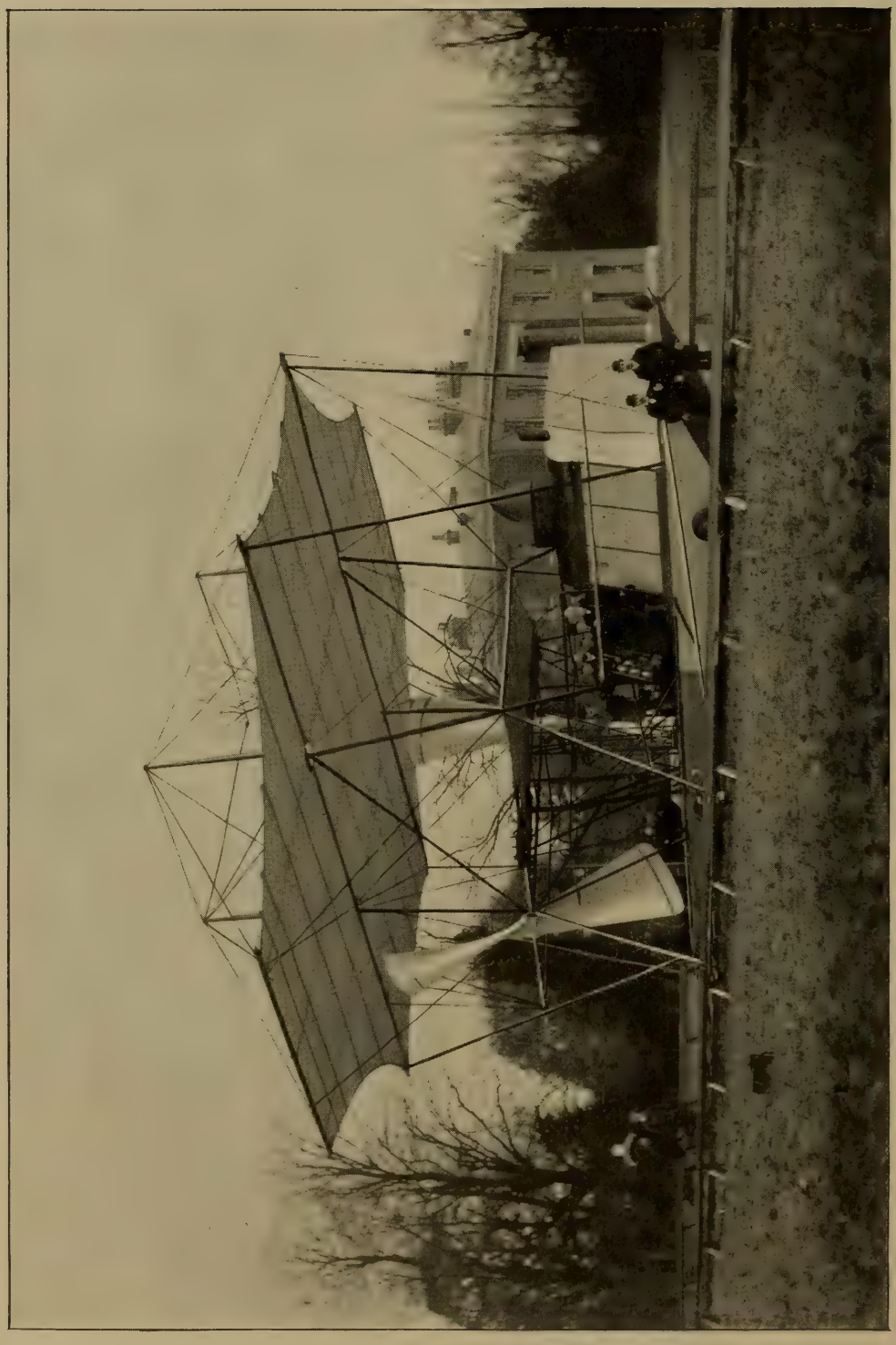
Mr. Maxim did not resume his experiments. He is understood to be engrossed by his great manufacturing interests in gun and shipbuilding, some of the profits from which may hereafter be invested in another flying machine. This will probably be provided with a petroleum motor, now being experimented with, from which he expects even better results than from the marvelous steam-engine previously built by him, which latter weighed, with its boiler and a condenser, less than 10 pounds per horse-power.

About contemporaneously with Langley and Maxim, Hargrave, in Australia, Phillips, in Great Britain, and Tatin and Ader, in France, besides many others, experimented with flying devices. Hargrave began in 1885, and produced about twenty working models, propelled by clockwork, by rubber, by compressed air, and by steam. His last steam engine weighed about 10 pounds per H. P., but he hopes to improve upon this with a gasoline engine. He employs for his models comparatively very large surfaces, as much as 5 square feet to the pound to be lifted, a proportion which may not be realised in full-sized machines, and hence requires speeds of only 10 miles per hour, with which he has succeeded in sustaining 79 pounds to the horse-power. He has invented the new form of kite which bears his name, and designs to suspend a motor and propeller, as well as himself, below a team of these novel cellular arrangements, and to fly through the air by towing the kites.

Phillips has been experimenting a long while, and has reached the conclusion that very narrow wings, somewhat like slats, are the most effective. He produced, in 1893, a machine looking like a Venetian blind on wheels, driven by a steam-engine. With this he is said to have lifted about 72 pounds to the horse-power, at speeds of 28 miles an hour, with surfaces in the proportion of one-third of a square foot to the pound of weight. The stability was, however, so defective that the apparatus, which weighed 402 pounds in all, could not be trusted in free flight, and made only brief skims. Tatin is a veteran experimenter. In 1879 he produced a flying model, driven by compressed air, with which he made many flights and had some breakages. In 1897 he produced, in connection with Dr. Richet, a model weighing 72 pounds, driven by a steam-engine. He obtained a lift of 55 pounds to the horse-power, with speeds of about 40 miles an hour, and surfaces of about 1 square foot to the pound; but the maximum flight was only 460 feet, much inferior to Langley's, and the equilibrium was defective. He says that he believes that he can overcome this defect, which has hitherto brought to grief every power-driven machine which has flown more than thrice, but this remains to be seen.

Ader is a French electrical engineer who has intermittently been engaged in aerial investigations for thirty years. He has built three full-sized machines, one, in 1872, to be driven by man-power, which, of course, was found inadequate; one steam-driven in 1891, at the expense of a banker, which produced indifferent results; and a third at the expense of the French Government, in 1897, which cost half a million francs. This was tested on the Satory field of manœuvres, with the most rigid precautions to guard the secrets of this war engine. The construction reproduced almost servilely the anatomical structure of birds. The surfaces were in the proportion of one-quarter of a square foot to the pound, and the whole apparatus weighed 1100 pounds. It was driven by a steam-engine of 40 H. P., weighing about 7 pounds per H. P., and was provided with screw propellers. The speed required for support was about 50 miles an hour, and the apparatus sustained 27 pounds per H. P., or somewhat less than Maxim's or Langley's.

No data have been published as to the tests, but it is said that wind squalls produced a quick descent, and that further experiments were abandoned. The equilibrium was probably so defective that it was deemed wise by the French Government to spend no more



MAXIM'S FLYING MACHINE

money on the machine. It was shown at the Paris Exhibition last year. All experts who have seen it agree that it is a wonderful piece of mechanical workmanship, that the motor is adequate, and that the wings are capable of sustaining all the weight, notwithstanding all their comparative exiguity.

The men above mentioned are but a tithe, perhaps a hundredth, of those who have been planning and experimenting with power-driven flying machines, but they are here picked out as the men who have accomplished the more notable successes. We now come upon a small group of investigators who believed that it was premature to apply artificial power to a flying machine until the proper arrangements and shape of the supporting surfaces were evolved, and their management in the air worked out by long practice.

First and chief among these was Lilienthal, a German engineer and physicist. During ten or fifteen years he made a series of elaborate experiments upon the best shapes for artificial wings, published a book on the subject, showing the superiority of arched forms, and, about 1891, brought out his first form of gliding machine, with which, after careful training, he was enabled to make many personal flights from hillsides, using gravity as a motive power. He gradually improved upon this with different machines, the last being a double-decker, weighing about 50 pounds, and carrying his own weight of 170 pounds in addition. The surface was 151 feet square, being thus in the proportion of about three-quarters of a square foot to the pound, and with this he made many glides, at angles of descent of about one in six, the maximum distance being 1200 feet, and depending, of course, upon the height from which he started. The timing of the flights showed that about 110 pounds were sustained per horse-power, at speeds of 23 miles an hour. In 1895 Lilienthal applied to his apparatus a carbonic acid gas motor of 2½ H. P., which was found, however, to affect the equilibrium so seriously that it was given up. He resumed gliding, and had, altogether, made about 2000 flights, with only trifling accidents, when, in August, 1896, he was upset in the air by a wind gust, fell, and was killed, to the great loss of aviation, which he would, doubtless, have advanced further.

Lilienthal was imitated by Pilcher, an English engineer, who modified the apparatus and made hundreds of glides between 1895 and 1899. His machine spread eighty-five hundredths of a square foot to the pound, and showed 100 pounds to be supported to the horse-power, obtained from gravity, at speeds of 25 miles an hour. He provided himself with a gasoline motor, but did not get far enough along to apply it. Towards the last he devised a method of starting up from level ground by towing the apparatus with horses, and in one of these experiments, in September, 1899, taking undue risks in order not to disappoint visitors, he was upset in the air and killed.

The writer of this has emulated Lilienthal and Pilcher, and thus far without disaster. He has confined his endeavours wholly to the evolution of automatic stability, making the supporting surfaces movable instead of the man, an arrangement the reverse of that of his predecessors. He has had about 1000 glides made by assistants, with two different types (five machines) without the slightest accident. The proportion of surfaces was three-quarters of a square foot to the pound, the speed, 22 miles per hour, and the weight sustained, 89 pounds per horse-power. He has been experimenting by proxy with a third type of movable surfaces, which he intends to test full-sized, and he holds that it is entirely premature to introduce an artificial motor.

Full particulars concerning the last three experimenters will be found in the "Aeronautical Annual"* for 1896 and 1897.

Since these experiments a further advance has been achieved by Messrs. Wilbur and Orville Wright, who have produced a double-decked gliding machine in which the operator is placed in

* W. B. Clarke & Co., Publishers, Boston, U. S. A

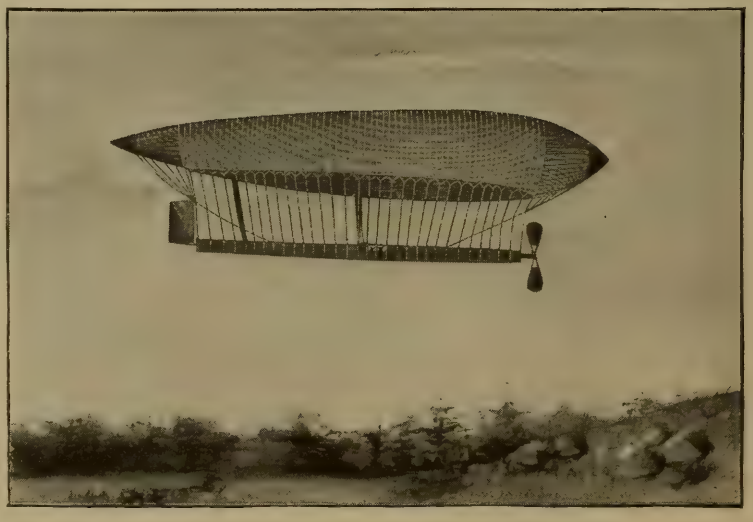
a horizontal position, thus opposing to forward motion 1 square foot, instead of 5 square feet, when he is upright, and they have further reduced the resistance of the framing by adopting improved shapes, so that the aggregate head resistances are reduced to about one-half of those which previously obtained. The experiments were made on the North Carolina coast, in the United States, in October, 1900.

ONE TYPE TESTED BY CHANUTE

The above is the record of what has been accomplished within the last decade in an investigation heretofore relegated to what have been termed "cranks." While a journey of 1200 miles has been made with a globular balloon, at the will of the wind, trips of only 5 or 6 miles have been made at the will of the operator, in calm weather, with fusiform balloons. With flying machines a maximum flight of three-quarters of a mile has been made by a model provided with a motor, and thousands of glides, up to 1200 feet, have been made by men-ridden machines with the aid of gravity, which latter power imposes no extra weight upon the apparatus and is always in good order.

The maximum speed of the dirigible balloon thus far is about 18 miles an hour, with eventual possibilities up to 44 miles per hour, while the speed of flying machines has already been about 50 miles an hour, with possibilities to 60 or 100 miles an hour, which speeds are attained by some swift birds. While fusiform balloons will, therefore, constitute one solution, and while they will be gradually improved and will serve in war, and perhaps in exploration, it now seems probable that future developments will chiefly appertain to flying machines. To make these a success the two main problems must be worked out; first, the motor, which must be very light; and, second, the stability, which is even more important, and which should be automatic.

To appreciate the difficulties appertaining to the motor, we may consider the difference in amount of power required for land and for aerial transportation. An American "Consolidation" locomotive will develop about 1000 H. P. and haul 2000 tons upon a level railway. Hence, it will haul 4000 pounds per horse-power. But this 1000 H. P., weighing, say, 100 tons with its tender, could impart a speed of only 57 miles an hour to Count Zeppelin's air ship,

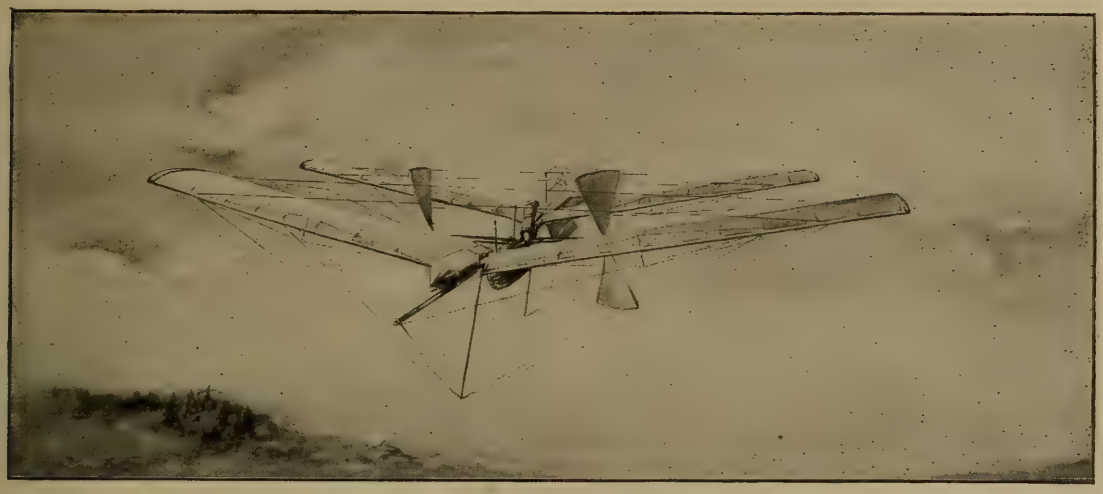


RENARD & KREBS' BALLOON

were this vessel (a manifest absurdity) able to lift the engine and to bear the resulting air pressure due to the speed. Neither could the locomotive sustain itself in the air if attached to a weightless flying machine.

We have seen that, with motor-driven apparatus, the best that has been positively done thus far has been to sustain from 27 to 55 pounds per horse-power by impact upon the air. Gliding machines, it is true, using gravity as a motive power, show 89 to 110 pounds sustained per horse-power, but these figures must be considerably reduced when an artificial motor is substituted, in order to cover the inevitable mechanical losses in the machinery and in the propeller. Much has been done within the past decade towards reducing the weight of motors. Steam-engines have been produced weighing but 10 pounds per horse-power, and the latest gasoline motor, that of Buchet, is said to weigh only 12½ pounds per H. P.; but much remains to be done to render machines working so nearly up to the limit of endurance absolutely reliable and safe in the air. Numerous and costly experiments are required to accomplish this. It now seems probable that the successful aerial motor will be some form of gasoline engine, using air instead of water as a working fluid, and thus saving weight. But those who know how tedious and slow has been the development of the steam-engine will have no very sanguine expectations of the early attaining of perfection in the gasoline motor.

It is still more imperative that the whole apparatus shall not fall by losing its balance in the air. It must maintain its equilibrium and be reasonably safe under all the vicissitudes of flight,—in starting, in sailing, in alighting, and in wind gusts. The bare statement of this requirement meets with ready assent, and yet how few of the investigators have the will or the patience to spend the time, and to take the risk, to learn the art of the birds by personal experiments with gliding machines. The writer has been advocating this method for some years, he has confined his researches to its advance, and he sees no reason to change his views.



THE LANGLEY FLYING MACHINE

The underlying principle of maintaining equilibrium in the air is that the centre of pressure upon the sustaining surfaces shall at all times be upon the same vertical line as the centre of gravity due to the weight of the apparatus. In calm air this is fairly secured, but in a wind the centre of pressure is constantly shifted by the turmoils of the air, for it advances or recedes with the diminution or increase of the angle of incidence. There are several ways of counteracting this difficulty. The centre of gravity may be shifted back or forward to coincide again with the vertical line passing through the new centre of pressure; this is the method employed

by Lilienthal and by Pilcher, which they applied by shifting the position of their personal weight. Or the centre of pressure may be brought back into a vertical line with a fixed centre of gravity, either by changing the angle of incidence, or by shifting the surfaces themselves. These latter are the methods which have been experimented upon by the writer in three different ways:—

1st. Affixing a horizontal tail (the Penaud tail) at an angle to the supporting surfaces. This catches the air on its upper or lower surface, and shifts the angle of incidence of the wings, and, consequently, the centre of pressure.

2d. Pivoting the wings at their roots, so as to move horizontally. These are arranged so that the impact of the air shall bring them back into the proper position.

3d. Pivoting the surfaces so as to rock vertically. This is arranged so that the impinging air shall automatically shift the angle of incidence, and, therefore, the centre of pressure.

The third arrangement is believed to be the best, but one cannot be sure, inasmuch as all the adjustments above indicated are most delicate. Simple as the principles seem to be, it requires years of experiment to apply them properly. The positions of the pivots, the strength and adjustments of restraining springs, and the best position for the centre of gravity involve thousands of cut-and-try experiments, first with models, and then with full-sized gliding machines carrying a man. The important feature is that the man shall remain stationary.

In regard to the shape of surfaces to be employed, Lilienthal demonstrated that concavo-convex wings, like those of birds, are far superior in supporting power to planes, and the latter have now been practically abandoned by aviating experts. The amount of sustaining surfaces experimented with has varied, as above mentioned, from ¼ square foot to 5 square feet to the pound of weight, this corresponding to speeds of from 50 miles down to 10 miles an hour, to obtain support. The amount required evidently depends upon the speed, but the larger the surfaces the greater is the weight. In the remote future it is probable that small surfaces will obtain, thus reducing the amount of required framework and the consequent head resistance, but until the problem of equilibrium has been fully solved it will be preferable to employ surfaces of about 1 square foot to the pound, involving speeds of 20 to 25 miles an hour in order to promote safety in alighting. With smaller surfaces we may hope to sustain eventually as much as 80 pounds per indicated horse-power, but something will depend upon the efficiency of the propeller.

The propeller is the next thing to be considered after the equilibrium has been secured and a reliable motor worked out. Both Hargrave and Lilienthal gave preference to flapping vanes over the screw propeller, but other experimenters prefer screws. It is yet too soon to draw definite conclusions on this question, and it opens a field for further experimenting.

We can, however, already calculate approximately the proportions, the strength and weight, the supporting efficiency, the speed, and the power required for a projected flying machine, so as to judge of the practicability of a design. Indeed, the mathematics of the subject have been so far evolved that engineering computations may eventually replace vague speculation in the domain of aerial navigation.

But after the problem has been worked out to a mechanical success, the commercial uses of aerial apparatus will be small. The limitations of the balloon have already been mentioned; such craft will be slow, frail, and very costly We are now sufficiently advanced in the design of flying machines to perceive some of their limitations. They will be comparatively small and cranky, require much power, carry little extra weight, and depend for their effective speed, on each journey, whether they go against the wind or with it, so that they cannot compete with existing modes of transportation in cheapness or in carrying capacity. It is true that high

speeds may be attained, and this may serve in war, in exploration, perhaps in mail transportation, and in sport; but the loads will be very small, and the expenses will be great. But flying machines will develop new uses of their own; and as mankind has always been benefited by the introduction of new and faster modes of transportation, we may hope that successful aerial navigation will spread civilisation, knit the nations closer together, make all regions accessible, and perhaps so equalize the hazards of war as to abolish it altogether, thus bringing about the predicted era of universal peace and good-will.

SUPERHEATED STEAM

By Ernest H. Foster

IT often occurs that a mechanical improvement attracts more or less wide attention for a time and then falls into disuse, even to the point of being almost forgotten, because of some apparently insurmountable obstacle, to be taken up again at a later date when the conditions governing its use appear to be more favourable.

In an address recently delivered before the Junior Mechanical Engineers' Society, the author stated this to be especially true as far as superheated steam is concerned, by which is meant steam which, immediately after its generation in the boiler, is raised to a temperature considerably in excess of the saturation point, without increasing its pressure, for the purpose of working it in a steam-engine in this condition. Considerable attention was given to this subject as far back as the year 1850, when we find numerous reports of engine tests which show most remarkable gains, ranging from 30 to 40 per cent., of work done with a given amount of superheated steam over the same weight of steam at a temperature corresponding to its pressure. These early experiments seem to have been practically confined to marine practice, possibly because this was the most active field for developing the steam-engine at that time, and some idea of the thoroughness of the investigation is obtained from the accounts of long voyages, covering several thousand miles, during which records were kept of the amount of coal burned when the engines were worked with superheated steam, and of corresponding voyages during which steam was used without superheating.

In his first volume of "Experimental Researches in Steam-Engineering," published in 1863, Chief Engineer B. F. Isherwood, U. S. N., discusses this matter carefully, and draws the general conclusion that while great economy is, doubtless, to be obtained by using superheated steam in engines, the extra bulk and weight of the apparatus required to produce the superheating, its vulnerability to destruction, but more especially the bad effects of superheated steam on the interior working parts of the cylinders and valves of the engines, chiefly due to the destruction of the lubricating oils before they have had a chance to perform their work, presented insurmountable obstacles which rendered the use of superheated steam at that time undesirable.

In spite of this carefully considered condemnation and Isherwood's apparent attempt to dismiss the subject as being the wrong line to pursue in steam-engine development, the question of superheating seems to have continued to attract wide attention. The saving in the coal pile was too great to be ignored, and engine builders and owners were tempted, by the reduction in operating expenses, to take the risk of inefficient lubrication and the other attendant difficulties, and so much progress was evidently made that we find

in Isherwood's second volume of "Experimental Researches," issued only two years later, even more attention devoted to superheating than before, and with quite different conclusions. In fact, superheating is there distinctly recommended, and the statement is made that an average gain in work done of about 33 per cent. may be counted upon. Isherwood recommended the steam to be superheated not more than 135 degrees, and suggested 100 degrees as an average which it is safe to assume because of the inability of the oil to stand a higher temperature without destruction.

The primitive form of the engine, the inefficient insulating covering, and the low pressure used at that time were conditions which undoubtedly lent themselves to making the use of superheated steam exceedingly advantageous, and the difficulties of lubrication, packing of stuffing-boxes, etc., must have been found to be very great in order to cause this practice to be discontinued for so long a time as it undoubtedly was. At the same time, the compounding of steam cylinders, the introduction of condensers, the improvement in valve gear and general construction, the increase of steam pressures, and other radical improvements were so rapidly brought into general use that the amount of work done per unit of steam was raised to a higher point than ever before, in spite of the drawbacks of moist steam.

As the superheater was lost sight of, the improvements which were being adopted in other directions were of such a nature as to diminish its importance. Let us examine these improvements to the steam-engine! Have they in any way interfered with it as a user of superheated steam? On the contrary, we find the steam-engine at the present time much more suited to the use of superheated steam than formerly. We now have mineral oils which will stand high temperatures without disintegration; we have stuffing-boxes packed with metallic packing; we have cylinders and steam pipes covered with a much more efficient insulating material; we have the wearing surfaces of cylinders and pistons machined to a nicety, and the interior surfaces often highly polished; we have improved forms of balanced and steam-tight valves. All these, with our present searching after every device to make the engine more economical, seem to open up a field for the superheater to an almost unlimited degree.

In Europe much encouragement is found in this belief. Americans have characteristically developed the line following the path of the least resistance, practically ignoring the question which had seemed to be set aside. In Great Britain, however, and on the Continent, in similarly characteristic manner, engineers seem to have been plodding along in the direction which they knew to be meritorious, gradually working out the problems and slowly overcoming the obstacles, until we now find them in a state very much in advance of their American brethren.

Great credit is due to that able Alsatian engineer, G. A. Hirn, and to his successor, Emil Schwoerer, and also to the German engineer, W. Schmidt, for keeping this subject alive. We find them with records of several thousand successful installations of large and small plants, and European engineers educated up to a point where no economical steam plant is seriously contemplated without including the superheater. Most of the records of these tests show a saving in steam or fuel ranging from 6 to over 20 per cent.

What is the reason for this increased efficiency of steam when superheated? Rankine discusses the question in his work on "The Steam-Engine."

1st.—We raise the temperature at which the steam receives its heat, and so increase its efficiency without producing a dangerous pressure. According to the law of efficiency of thermodynamic engines, the heat transformed into mechanical energy bears the ratio to the whole heat received by the fluid as the range of temperatures is to the absolute temperature at which the heat is received, thus:—

$$\frac{T_1 - T_2}{T_1 + 461.2}$$

The more heat supplied per unit of volume of steam to the engine, the more work can be obtained from the engine, and as the increase of pressure has a practical limit, this extra heat is to be obtained by superheating the steam.

2d.—The diminished density of the steam employed to do the work lessens the back pressure, or, as commonly expressed, improves the vacuum. This also applies to the air and vapour which are carried with the steam and are further expanded by the increased heat, and are consequently contracted to a much less volume when chilled by striking the cooling surface of the condenser; thus the air pump has less work to do.

3d.—The prevention of condensation during expansion without the use of steam jackets, and in a much more effective manner. This is the most important advantage to be attached to the use of superheated steam. Steam jackets are wasteful and inefficient when applying heat to the engine,—inefficient because the contact is only with the steam immediately adjacent to the walls of the cylinder, with probably little effect on the steam in contact with the piston and in the interior of the cylinder out of reach of the radiation from the walls; wasteful because of the full effect of heating the exhaust steam after it has done its work in the cylinder during the waning stages of expansion and throughout the exhausting stroke. This is particularly true of engines which have an appreciable pause at the end of the stroke, which pause always finds the cylinder full of steam, having completed its work in the cylinder and being ready for exhaust. Ample evidence of the truth of this statement is found in the high ratio of water condensed in the jackets of direct-acting engines to the amount of steam used in the cylinders.

The use of superheated steam is bound to have an important effect on the question of jacketing cylinders. If the superheating is sufficient to carry the steam through the engine to the point of final exhaust without reaching the saturation limit, there is evidently no use for steam jackets. This, however, necessitates the careful covering of the cylinder walls and steam passages to prevent as much radiation as possible, and the logical development of this question would seem to be to abandon the low-pressure cylinder jacket first, and follow by giving up the intermediate, and finally the high-pressure jackets, and substitute for the jackets ample intermediate reheaters between the cylinders, so proportioned that each cylinder would exhaust its steam at a point just sufficiently above the temperature due to the pressure to insure the absence of any condensation.

The using of perfectly dry steam and the elimination of water of condensation would seem a very practical advantage of superheating. Water is a very disturbing element in steam-engines and pipes at all times. It increases the friction of the wearing surface, interferes with the lubrication, and chokes up the discharge; it produces unequal strains in the metal, due to different temperatures, and often causes leaks at joints which remain perfectly tight under dry steam. Dripping at stuffing-boxes is also avoided in this way.

It has always been difficult to determine the actual amount of moisture which is contained in steam. Some light is thrown on the subject by the use of superheated steam. For instance, at a working pressure of 125 pounds, 1 per cent. moisture would represent about 20° of superheat. We find, under the best conditions of properly proportioned and well covered steam pipes, a loss of $\frac{1}{5}$ to $\frac{1}{3}$ of a degree Fahr. of superheat per foot of steam pipe. It would not be out of reason to assume that, with the ordinary large and indifferently covered steam pipe, the loss would reach as much as 1 degree Fahr. for every foot of pipe; consequently, a pipe 100 feet long might lose 100 degrees of superheat, corresponding to 5 per cent. of moisture in the steam, provided the steam was dry on leaving the boiler. Assuming $\frac{1}{2}$ degree loss per foot, we should have a condensation of $2\frac{1}{2}$ per cent. in a steam pipe of this length.

As the friction for superheated steam is much less than for saturated steam in

passing, there is not so much loss in ports and passages, and the size of the pipes may be considerably reduced. The tendency in the United States has been to use steam pipes which are much too large. Good practice with superheated steam recommends that the velocity should not be less than 100 feet per second passing from the boiler to the engine. Of course, this means ample steam receivers in proximity to the engine, and a very good plan would be to have these receivers fitted with reheating tubes containing steam which is being circulated through the superheater, or else a portion of the hot furnace gases diverted from their course for this purpose and returning again to the boiler flue by means of an induced draught.

Having once evaporated water into steam at an expense of 1000 or 1100 heat units, why allow it to condense and part with over 800 of the heat units before doing its work and rush forward more steam to take the place of that which is lost, instead of supplying the necessary heat for the re-evaporation, thus saving the heat originally expended?

As to the effect of superheated steam on lubricating oils and stuffing-box packings, it may be said that the present practice provides, and, in fact, already demands, oil and packing which will easily withstand the more severe conditions. Mineral oils have supplanted the old vegetable oils which were formerly used with machinery, and metallic steam packings have been universally adopted. Both of these were necessitated by the temperatures due the steam pressure in the vicinity of 150 pounds to the square inch, which is now common practice; hence, we already have the way thoroughly paved for the introduction of superheated steam.

We have mentioned Continental practice in this direction. There we find no prominent central station designed without providing for superheated steam. Engine builders make guarantees contingent upon it, giving an advantage averaging about 12 per cent. in pounds of steam per horse power based upon the steam being superheated. The range of temperatures has resolved itself into recommending the use of steam at between 500 and 600 degrees Fahr. Good practice there may be said to lie in the vicinity of 570 degrees. Experimenters have observed that steam expands more rapidly during the first 20 degrees of superheating than when further raised in temperature; consequently, the first effects are proportionately more beneficial.

The method of constructing the superheater naturally presents the most important aspect of the situation after deciding that the results are beneficial and desirable.

Dismissing the subject of superheating by means of wire drawing as being inefficient and impracticable, the methods resolve themselves into a system of tubes or pipes through which the steam is passed after leaving the boiler on its way to the engine, these pipes being exposed to the hot furnace gases, either in connection with the steam boiler itself, or in a separate setting having a fire of its own. In large plants it is usual, and even more desirable, to set the superheater by itself, and it is placed alongside of the boiler as a continuation of the battery, with fronts and setting similar to the boilers, and fired in the same manner as the boilers. The fact that the results are found to justify such an addition to the plant is the best testimony in favour of superheating.

Much rivalry exists between the use of cast-iron and wrought-iron tubes for superheaters, and there seem to be well-defined governing conditions in different instances where either one or the other is found the more desirable. For general use, however, the author unquestionably leans toward the cast-iron construction, believing that it possesses greater durability, and because of the greater mass of heated metal which serves to maintain the temperature of the steam at a more even point, regardless of not being so much affected by the working of the fire. For example, when the fire door is open, the blast of cold air entering has a chilling

effect on the superheater, and is much more pronounced if the tubes are of light wrought-iron construction than if they are made of cast iron with greater thickness.

The objections which are raised to the use of cast iron in boiler construction cannot apply to superheaters. The presence of water in a boiler gives rise to unequal temperatures which produce severe internal strains in the metal, whereas a superheater contains no water, and the comparatively even temperature of the steam relieves the metal of all strains except those due to the steam pressure simply. The cast-iron superheaters which the author inspected had great strength and durability. Some of them had been in use for six years without giving the slightest trouble or showing signs of deterioration.

The point of application of this type to the boiler varies with the construction of the latter. For instance, the most favourable location on a Babcock & Wilcox boiler is immediately over the tubes and under the shell; the same is also true of a Heine boiler; but, at the same time, a good arrangement may be made in either of these types by placing the superheater back of the bridge wall and underneath the tubes. In the independently fired boiler of the marine type the superheater may be placed in the main flue or at the back of the boiler where the gases are turned up to enter the tubes. In an ordinary return tubular boiler the flue at the back, immediately at the entrance to the tubes, is a very appropriate place for the superheater, since, on account of the high temperature at that point, the heating surface may be distributed with great efficiency. The Power Specialty Co., of New York, are the exponents of this type of superheater in the United States.

The wrought-iron construction for superheaters undoubtedly has its useful field. The lightness and compactness of this form of apparatus are greatly in its favour. With well assured circulation, a comparatively low temperature of hot gases, and, especially where a moderate degree of superheating is required, good results should be obtained. The Babcock & Wilcox Company make a simple and ingeniously arranged superheater of this type, consisting of two cast-iron headers set parallel and adjacent to each other with openings facing in the same direction. The headers are joined by rows of 1¼-inch wrought return bends which extend out into the hot gases. This arrangement is well adapted to the popular form of the Babcock & Wilcox boiler, and efficiently utilises the triangular space between the horizontal drum and the tubes.

Aside from its application to steam plants where the engine is in close proximity to the boiler, the superheater has an immense field as a relay agent. In large plants where steam is conducted from one central boiler plant to other buildings, often at a considerable distance, a superheater with a comparatively small gas, oil or coke fire may be placed at the far end of the pipe, and will add enough heat to the steam to not only evaporate all the moisture produced by loss of heat in transit, but to raise the temperature to such a degree of superheat as to increase its efficiency in the engines, as before mentioned.

A large plant of this sort was inspected by the author in a steel works and rolling mill at Rothe Erde, Germany. In this case there were fifty Cornish boilers, aggregating 54,000 square feet of heating surface. Superheaters were fitted to each boiler in the side flues, while three independently fired superheaters were placed at the termination of a steam pipe, 1000 feet long, leading from a battery of twenty-four Cornish boilers. Oil fuel is burned in these works, and the officers of the company stated that the superheaters had been in use since 1896 without giving the slightest trouble, and that repeated tests had shown a saving in fuel at the former plant of from 17 to 20 per cent., while, in spite of the long steam pipe and numerous branches, the latter installation showed an increase in economy of from 10 to 13 per cent.

In this plant and many others all types of slide-valve and Corliss and

poppet-valve engines were found working with superheated steam, and the author was unable to secure any testimony of a nature derogatory to the practice or which would suggest the necessity of providing any special means for lubricating under such conditions.

As to the actual results which may be promised to any prospective user of superheated steam, the author will content himself with the statement that this depends entirely upon the surrounding conditions. That some benefit may be derived is without question. It is a remarkable fact that throughout all the mass of evidence which has been accumulated during many years, one result seems to be universal,—however vague or incomplete the recorded data, —superheating always results in a considerable economy of steam used.

After all, a conclusion of this sort is about all that could be expected from a mass of reports, from widely different sources, of tests made according to no common standard. In such cases the data are bound to be incomplete, but not altogether without value on this account. If we find such important items omitted as the temperature of the fire, rate of combustion, temperature of escaping gases, efficiency of boiler, amount of draught, etc., these tests may be regarded of less value from a scientific point of view, or as an aid to the constructor; yet we are glad to have them for the assistance which they give us in forming an opinion of the general subject.

The author feels convinced that much improvement in steam-engine economy may be obtained by using superheated steam, even in the highest class of engines of the present day. The superheating of steam will probably give the triple-expansion engine somewhat of a setback. There are records of tests under which a compound engine with superheated steam has given better results, under similar conditions of work, than a triple-expansion engine.

The arguments bearing on this case would be too lengthy to mention here, but it will be readily admitted that, with the use of superheated steam, some of the reasons for the multiplication of steam cylinders disappear. We expect to see an indicated horse-power easily developed with 10 pounds of steam per hour in a compound engine, and already have records of 10.12 pounds for an indicated horse-power per hour on an 800-H. P. compound Corliss engine in Europe.

The effect in fuel saved is not necessarily in the same proportion to that of steam saved by employing superheaters. Many tests show a larger proportion of fuel saved than of steam, while in others these relations are reversed. The superheater virtually adds to the heating surface of the boiler. It may truthfully be claimed to utilise this surface more efficiently. In a well-proportioned plant where the waste gases are rejected at a low temperature, the net gain by superheating will obviously be less than in a plant where available heat is allowed to find its way to the chimney. We are always sure of some improvement, but each case must be considered by itself in determining the amount.

THE SMOKE FROM A GREAT CITY

SOME PRACTICAL EXPERIENCE WITH PREVENTIVE MEASURES

By Professor C. H. Benjamin

WAS it not Tyndall who said, "Dirt is simply matter in the wrong place"? So we might say of smoke. What is commonlyt known as smoke is simply carbon in the wrong place.

There are various kinds, some agreeable, and some disagreeable; the smoke of incense and the smoke of sacrifice in the days of old were agreeable to the priest, and presumably to the worshipper. In our own day the smoke of a good Havana or of a pipe of fine cut is not objectionable to the club man and the lonely bachelor.

The smoke from coal fires in the country is a small matter and does not give offence; but with the concentration which results in large cities the smoke nuisance, like sewage disposal or water supply, becomes a serious problem. Where only a few tons of coal are burned, and that under chimneys far apart, the pollution of the atmosphere is hardly noticeable; but with the gradual aggregation of large manufacturing plants, burning sometimes hundreds of tons a day, and the erection of towering office buildings, as in the United States, containing scores of rooms and giving shelter to populations as large as that of a small town, the black smoke resulting from the burning of ordinary soft coal has become a distinct menace to cleanliness, comfort, and health. Unfortunately, the smokeless coals, the anthracites and the semi-anthracites, are expensive in comparison with the various grades of bituminous coal. The soft coals are much more abundant, and as the supply seems inexhaustible, they will probably continue to be the chief fuels used in the various kinds of manufacturing for a long time to come.

It is useless to try to prevent manufacturers and business men from using the cheaper fuel. Soft coal is destined o be the principal fuel in all large cities, and wherever great manufacturing establishments are located. The problem, then, is one of burning bituminous coal with the least possible amount of objectionable smoke.

There is a probability that soft coal may be roasted or coked on a large scale and reduced to its elements of coke, fuel gas, and various by-products. That this can be done without any serious amount of smoke has already been demonstrated in numerous instances. Coke then becomes available as a smokeless fuel for use in blast furnaces, locomotives, and wherever a forced draught is available; while the fuel gas has, as good points, cheapness, ease of distribution, and the possibility of use either as a smokeless fuel under the boiler or directly in the explosion chamber of the gas engine. The writer believes that, with the improvements which are constantly being made in

ONE HUNDRED PER CENT. OF SMOKE

BEFORE APPLYING SMOKE PREVENTIVES

coking processes, this method of obtaining heat from bituminous coal will rapidly come to the front.

In the meantime, however, we must try to do away temporarily with the discomfort and expense attendant on the direct burning of fuels which contain hydro-carbons. That this is entirely practicable, from a mechanical standpoint, has been clearly shown in an article by Mr. W. H. Bryan in this magazine for November, 1900. Ten or twelve years ago the possibility of preventing soft coal smoke was doubted by very many, largely because of the crudity of many of the earlier devices proposed; but persistence and ingenuity have triumphed, until to-day we can safely count on perhaps eight or ten successful stokers and smokeless furnaces.

Having now a remedy, there comes, however, the still more difficult problem of how to apply it. Well-meaning reformers have attempted to frame statutes and ordinances which would regulate this particular evil; but, as is frequently the case, their zeal has not been tempered by discretion, nor seasoned with accurate information, and as a result the majority of the laws so prepared have failed when put to the tests of the courts. An ordinance sometimes called for the entire suppression of smoke when it was easily proved before the court that this is a physical impossibility.

In other cases, the ordinance has been so framed as not to clearly distinguish between the responsibility of the owner for having his boilers equipped in the best manner for abating smoke and the limited responsibility of the engineer or fireman for keeping the plant in order and using it properly.

To turn to a concrete example, it may be interesting to see what is being done in one of the large American manufacturing cities, to study the difficulties there encountered and the methods used in overcoming them. The city of Cleveland in the past fifteen years has had the usual experience of other towns with various ordinances more or less effective; with arrests and fines, or, as was more often the case, continuances and acquittals; arrests which defeated their own object in antagonising the very men who must be depended upon to solve this problem, if it is ever solved; fines so ridiculous in their smallness as to have little effect, save to irritate; and

THE SAME CHIMNEY AFTERWARDS

the spasmodic ups and downs of reform which are so well known in American cities.

Continual agitation and study of this subject, however, had effect in educating the people, and in changing the general sentiment. Many manufacturers and business men began to realise that it was their duty, as lovers of their own homes and public buildings, to reduce the smoke evil to as low a limit as possible. This feeling gradually crystallised in the appointment of a committee by a municipal association to study smoke prevention and determine on the best course of procedure. As a result of a careful investigation it was decided that, in the first place, the reform must be removed from political influences. The usual tenure of city office, two years, was too short a time to devote to an undertaking of this character, and the uncertainty of a longer tenure would make the efforts spasmodic and inefficient.

Through the efforts of this association the Ohio State law was so amended as to make it applicable to Cleveland. A separate division of the city work was created, having the matter of smoke abatement in charge, and a supervising engineer and staff of assistants authorised. After the passage of ordinances by the city council providing for local details of the work, the supervising engineer was appointed by the Mayor for a term of five years.

With a suitable office force provided, and a clear field, unencumbered by precedent or example, it next remained to determine what policy should be adopted. The old method would be that used in the case of misdemeanours and petty infractions of the municipal law in other departments, namely, the obtaining of incriminating evidence by one way or another, perhaps notices to stop or abate the smoke, followed finally by arrests and trial in a police court.

As before intimated, however, the success of this policy in the past had not been such as to warrant its continuance. Arrests did not usually result in convictions, and when they did the fine was paid, perhaps, but the quantity of smoke did not diminish; a spirit of hostility on the part of both owners and manufacturers was developed by this persecution, as they regarded it. It was thought best to make use, at first, of milder methods, and if a thorough trial should prove them inadequate, then, and then only, to resort to legal measures.

It was decided to proceed with the assumption that most citizens, even if engaged in manufacturing, were interested in the healthfulness and good appearance of the city, and would lend their aid to the movement if approached in the right spirit and if convinced that

THE SMOKE PREVENTER JUST TURNED ON

it would not result in financial loss to them as individuals.

It is not necessary to demonstrate today that smoke can be prevented to a large extent. Scores of large business blocks and manufacturing establishments in Cleveland show this to the eye "that he who runs may read." It does become necessary, however, to prove that a man may be a good citizen, reduce the smoke from his chimney, and at the same time benefit his own pocket-book.

Scores of letters written to those who had already installed mechanical stokers or other abating devices, partly, perhaps, from an interest in the cleanliness of the city, partly from motives of economy, brought back answers almost unanimous as to the wisdom of such investment. Artemus Ward once remarked with regard to Shakespeare, "that his neighbours not only cherished

his memory, but made it profitable cherishing," and so these men had not only done the right thing from an ethical standpoint, but had, at the same time, reaped corresponding financial benefit.

In Cleveland, even the business portion of the city, with its tall office buildings, dry goods shops and others of various kinds, is comparatively free from smoke. Out of forty modern business blocks within a radius of a quarter of a mile from the business centre, three-fourths are already provided with furnaces which are practically smokeless. And it is safe to say that no company erects a modern office building in that city without seriously considering the smoke problem, and adopting what is considered the best means of solving it. As the older buildings are gradually torn down to make room for modern structures, the conditions will steadily improve, and probably ten years from now this part of the city will be practically free from the nuisance.

Cleveland is largely a manufacturing town. There are located within its borders from fifteen to eighteen hundred boilers of all kinds, to say nothing of the cupolas, melting, and annealig furnaces, each one giving up its murky tribute to the prevailing gloom. In the early morning a dense cloud of smoke gradually gathers over the centre of the iron and steel industries of the city, rises like some mushroom growth high above the buildings, and is blown, a streaming black cloud, either out across Lake Erie, or back across the city, where it changes the whole face of nature.

A GOOD EXAMPLE OF SMOKELESS FIRING

As one sails from Buffalo to Cleveland on the night boat, and approaches the latter city in the hours just after sunrise, he distinguishes it first by this black cloud which is gradually rising from the shore, and can locate it thus long before the buildings and the towering stacks themselves become visible.

But even in this discouraging locality the mechanical stoker, the down-draught furnace, and the steam and air jet are gradually gaining foothold. The last reports show nearly six hundred smokeless furnaces of various descriptions, each of which, in its particular locality, is reducing the smoke average from, perhaps, 50 per cent. down to 10 per cent. What this difference really means only one who has studied both sets of condition can realise. Even in the heart of the manufacturing district there are chimneys showing scarcely a trace of soot, standing over boilers just as large and furnaces just as hot as those under their smoky

neighbours. They are not only shining examples of what should be, and what might be, but, at the same time, are a source of profit to their owners.

Experience has shown that it is useless to judge any chimney by mere casual observation. The chimney which is seen often is the one that smokes. The chimney which you see only occasionally may never be detected in the forbidden indulgence. It is only by systematic observations, covering comparatively long periods of time, that it is possible to judge impartially and accurately of the relative smoke conditions.

The method of making observations which has been adopted in Cleveland, and which, so far, has been found reliable and satisfactory, is to first select some point of view which shall give a command of twenty-five or thirty chimneys easily visible, this point usually being the top of some comparatively high building. Then, beginning, we will say, at eight o'clock in the morning, the condition of each chimney, in turn, is noted on a scale of four, four considerable accuracy; this is done at five-minute intervals for two hours, giving in all twenty-five observations of each stack.

These notes being entered upon a sheet especially ruled for the purpose, a simple adding of twenty-five observations gives the average on a scale of one hundred; as, for instance, if all the readings had been four, the sum would be one hundred; if two, the reading would be fifty, and so on. The next time that observations are made, some different time of day is chosen, these two-hour sets being repeated four or five times and the final average made. The net result thus covers a period of eight or ten hours, or the ordinary working day. Although this method of grading may give slightly different totals from different observers, the difference is not found to be serious, and the relative standings are not thereby affected.

The supervising engineer now has something tangible on which to base his criticisms. Experience has shown

WHEN THE DRIVERS SLIPPED

meaning dense black smoke, and zero practical freedom from smoke. These observations are repeated every five minutes, the judgment of the observer being depended upon to determine the relative amount in each case. A little practice will enable one to do this with

that merely calling the attention of the owner to the fact that his chimney is smoking prompts him only to change the subject by calling your attention to other chimneys within the range of his office windows which smoke far worse than his. It has seldom been the lot of

the supervising engineer to find a chimney which could be seen from the office windows of the owner. But when, by inspection of such a report, the owner sees that his chimney is one of the worst offenders in his locality, he is disposed to give the matter serious consideration. On the other hand, if the scale in his case is light, the feeling of pride in his superiority immediately makes him a friend and co-operator in the work of smoke abatement.

Reports of these averages are sent to every owner, showing him his own

THE OLD AND THE NEW, SIDE BY SIDE

standing and that of his neighbours, and, in the case of more serious offenders, this is followed up by a personal visit. In some cases the appeal is made to the civic pride of the proprietor, and this may be productive of good results; but in the majority of instances the economic argument is the only one which prevails, —reference to the experience of others, and claims of economy, backed up by figures.

It is necessary to be very careful in recommending this or that device, so that there may be no claim of prejudice or favoritism. Officials, however, do not hesitate in plants which are new, or just being equipped, to recommend the introduction of mechanical stokers, especially if there are several boilers in the plant. In other cases, where the boilers are old, or few in number, and likely to be soon replaced by new ones, it would seem too great a hardship to require the purchase of stokers which would, perhaps, cost nearly as much as new boilers. In such instances a remedy is sought in the use of steam and air jets.

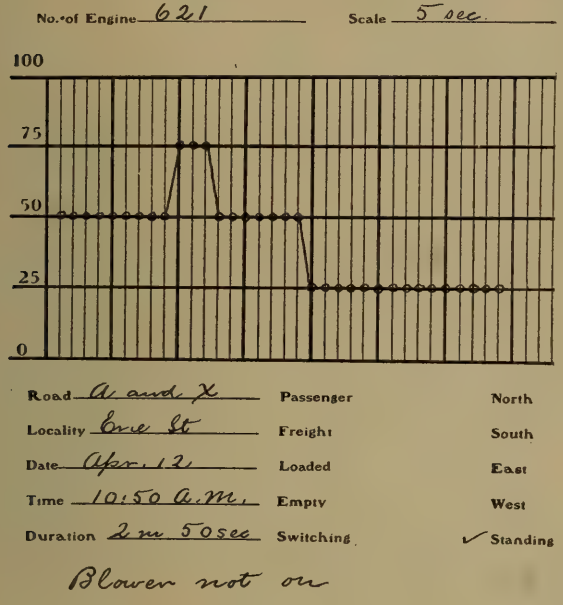
These latter devices simply take advantage of the fact that immediately after firing with fresh coal an additional supply of air is needed which should be thoroughly mixed with the escaping gases in the rear of the furnace. An automatic steam jet and air damper which is thrown into action by the opening of the fire-door, and is then gradually but automatically closed by the pressure of weights or a water column, has proved a good smoke preventer and fuel saver.

Steam jets, when not automatic and requiring to be turned on and off by the fireman, are apt to be neglected; and steam jets which are not of the proper shape, and do not spray the steam in such a way as to mix the air with the coal gases, are ineffectual; but the automatic types have, in many cases, reduced the smoke to 5 or 6 per cent., and reduced the fuel bill 10 or 15. These devices are sometimes the invention of the engineer, and as long as he remains in charge of the boilers they are usually made to work, because of his interest and care.

In Cleveland the smoke from locomotive, steamer, and tugboat boilers is sometimes more objectionable than that from stationary chimneys. In these types of boiler the stacks are usually low, and the use of the forced draught throws out the smoke in great volumes. Where a railway passes through a city between buildings on either side, the escape of smoke from the stacks of the engines is particularly objectionable to the occupants of the buildings. On some railways the use of hard coal or coke has justified the increased expense, by reason of the greater comfort and cleanliness of the trains, and in some cities the use of smokeless fuel has been compelled by city ordinance. Mechanical stokers are with difficulty applied to locomotive engines, and it is doubtful if they will ever be successful with them on any extended scale.

Careful experiments and observations on the part of engineers of some rail-

ways has shown, however, that it is possible to reduce the smoke a very considerable amount by careful firing. The so-called one-shovel system of firing has been adopted on some lines, and has

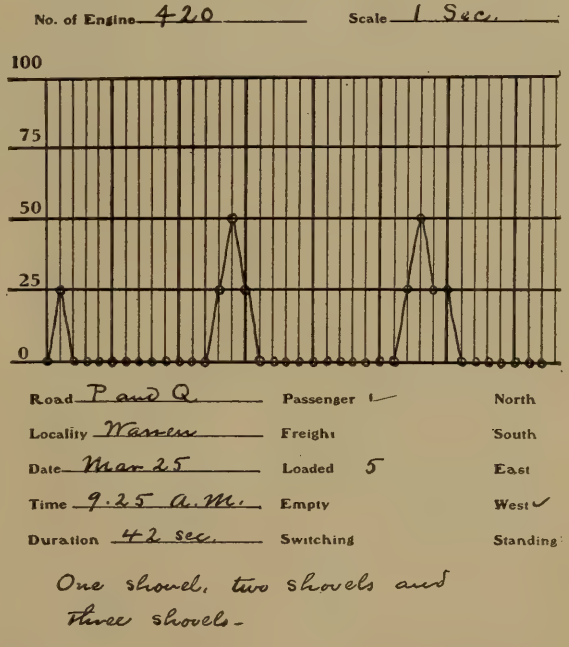


A LOCOMOTIVE SMOKE RECORD

not only reduced the smoke, but has been productive of considerable economy in fuel.

When this matter was brought to the attention of the superintendents of the leading railroads entering Cleveland it was mutually agreed that each would do what he could to bring about a better condition of things. The quite general introduction of brick arches in the fireboxes of locomotives has been a great assistance in this work. Combustion tubes, supplying additional air over the fire, and fire-doors with the upper half open for the same purpose, have also helped. But, with all these, the principal improvement has been found in the fireman and engineer. It is the man behind the shovel who must be relied upon in this branch of the work.

One of Cleveland's smoke inspectors devotes all his time to the railroads, and a new method of taking observations has been adopted, entirely different from that used in the stationary work. In observing the smoke from a locomotive, time is one of the principal elements to be considered. The locomotive appears in the distance, comes, and is gone, with, perhaps, a total time of observation of only forty or fifty seconds. To facilitate the work of the inspector, and also to present the conditions more graphically to the eye, the cards shown on this page have been adopted. The vertical distances show the percentage of smoke on a scale running from zero for no smoke, up to 100 for the dense, black variety. The horizontal distances represent equal time intervals varying from one to ten seconds, according to the speed of the train. The time is determined by counting regularly, and dots are placed on the vertical lines to represent the smoke average at that instant according to the judgment of the observer. The necessary data with regard to number of engine, service, direction, etc., are entered on the blank form, and the dots are connected by lines producing diagrams such as shown. These are readily made in duplicate by the use of carbon paper,



THE ADVANTAGES OF THE ONE-SHOVEL SYSTEM OF LOCOMOTIVE FIRING

and the duplicates are turned over to the master mechanics or road foremen of the respective railroads. This is done at quite short intervals to enable the officials to locate the difficulty before the circumstances are forgotten. In

some instances particular attention is called to failure to use the blower while standing, to exceptionally heavy firing, and other faults which are apparent to the inspector.

The employment of a trained railroad man for this work gives his criticisms considerable weight. To illustrate the effectiveness of this method of work it is only necessary to call attention to some of the averages made by different railways in Cleveland before and after the turning-in of these reports. During the two weeks following March 1, 1901, observations on from fifteen to twenty engines on each of five important lines showed an average of from 20 to 35 per cent. of smoke, with a general average of about 30. After sending in reports of these observations, and waiting a little time for the railway officials to do their part, similar observations were made on about the same number of engines for each road under about the same conditions. An average of these gives the rather remarkable result of averages ranging from 11 to 15 per cent., with a general average of about 14, or less than half that of the two weeks before. As there had been no change in the equipment or the personnel of the railways in the interval, this gratifying reduction could be attributed only to the care used in firing, and is a successful demonstration of the advantages of the one-shovel system.

It is not necessary to remark, perhaps, that this also meant a reduction in the fuel bills. By way of illustrating the difference between one, two, and three shovels of coal on a fire, reference is made to the lower one of the diagrams on the preceding page. It will be noticed that, on the application of one shovel of coal, as in the first peak shown, the smoke ran up to 25 per cent. and dropped immediately to zero, the interval between two seconds. Two shovels on the second firing gave smoke to the extent of 50 per cent., lasting four seconds. Three shovels, while giving no blacker smoke than the last, prolonged the interval five seconds.

Although it is idle to talk about prevention of smoke as long as soft coal is burned, there is no doubt that, even without the use of smoke preventers, the amount can be very largely reduced by careful firing, and with a saving to the owner. It may be possible to bring about some similar improvements on tugboats, and with the aid of steam and air jets, which have been successfully applied in several instances, the smoke from this part of traffic may be brought down to respectable limits.

GOLIATH CRANES

By Joseph Horner

THE essential difference between the goliath and the gantry crane, as the terms are understood in Great Britain, is that the first carries a crab on the horizontal beams, the second a jib crane. That distinction may not appear to be of much importance, yet it widely differentiates the functions of the two types. The term goliath crane in Great Britain denotes but one type, — that in which a bridge, supported on tall end-framings, carries either a crab or a trolley. Though sometimes fixed, it far more frequently is portable. But the American gantry cranes correspond in their general features with the British goliaths, since they also have the end framings, supporting a bridge, along which a trolley travels. In America and on the Continent they are also termed bridge cranes; in Germany, portal cranes.

True, gantry cranes are chiefly limited to wharf work, and some classes of erecting in which it is necessary that the range of hoisting shall cover an area larger than the span of the gantry. The crane jib extends beyond the span and lifts from, and lowers into, ships' holds. It combines, therefore, in one, the most valuable features of the traveller, and of the jib crane. The type is mostly operated by steam, but in recent years electricity also has been applied The steam gantry crane consists of a crane superstructure, usually fixed on the beams of a goliath framing, though sometimes made to travel on this. The crane itself differs in no detail from that of the common steam crane with ordinary side frames, post, jib, and gearing. The post is usually fixed in a centre bed, or base, bolted between, and on the main girders, and the crane slews around on it. The jib may, or may not, have derricking arrangements. The crane is almost invariably set at one end of the gantry beams, and but rarely in the centre, so that the jib shall overhang the end to the fullest extent, while, when slewed round, its load can be deposited in trucks on a railway line between the span. Such cranes frequently have jibs of great length. The single term gantry is applied to any overhead bridge or cantilever on which a crab or trolley runs. Thus, a shipping gantry is used for hauling materials over ships or barges for transportation. A block-loading gantry is a structure of this kind used in harbour work.

Features which are possessed in common by goliath and gantry cranes are portability, and the leaving of a clear, open way between the supporting end-framings. The special value of these types consists in the combination of these features. Of the two, however, the goliath cranes have the larger range of service, and there are greater differences between the true goliaths than exist between these and the gantry, or dock cranes. The construction of portable goliath cranes would not, at first, seem to offer much scope for variation in design. Nevertheless, many differences are found. This is due to the extensive and varied services to which this kind of crane is applied, and to the numerous conditions under which they are operated.

The true goliath or bridge cranes are the lineal descendants and the modern representatives of the old Wellington

TEN-TON HAND GOLIATH CRANE. BUILT BY THE SOUTHGATE ENGINEERING CO., LTD., NEW SOUTHGATE, ENGLAND

cranes, in which the trolley, or jenny, traversed the beams of a goliath framing. At one time, loads of ten tons were considered heavy for goliaths; but they are now frequently made of forty, fifty, or one hundred tons capacity. The occasions for this development lie in the ever-growing use of concrete for the blocks of breakwaters, piers, and for harbour work generally; in the demands of stone quarries, of bridge builders the requirements of steel works for te' transportation of ingots, and in the proving grounds of gun manufacturers.

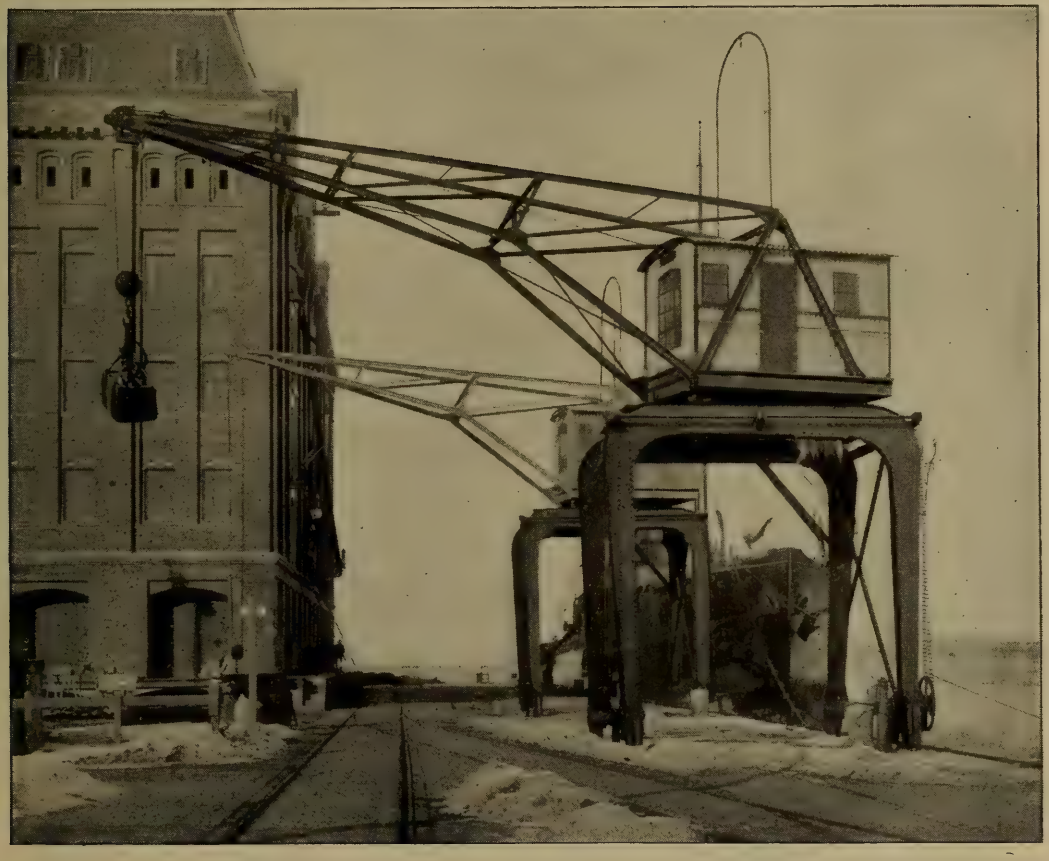
These cranes fulfill the same functions in the sheds and yards that the travellers do in the shops. They are portable, yet they do not encroach on floor space, as the portable cranes do. They possess, further, the advantages of a direct vertical lift, like that of the travellers. The span, height, and power of different machines are variable within an extremely wide range. They are operated by hand, steam, electricity, and occasionally by hydraulic power. The stresses in the bridge girders are similar to those in the girders of travellers. The crab or trolley traverses, like the crab or trolley of a traveller; or, alternatively, a jenny is operated from gearing placed on the end verticals. Timber, iron, or steel are used in their construction. These are points of similarity between the family of goliaths and travellers.

But the fact that the goliath travels on the ground instead of on an overhead runway introduces several important points of difference. The construction of the tall end-framings involves careful design, since they are subject to severe cross-working, and to end-long stresses, due to the traverse of the crab. The transmission of the driving force to the travelling wheels on the ground involves also some trouble,—some problems which are not met with in travellers, in which the wheels are operated directly by gearing, driving from the travelling shaft to the wheel axles adjacent. In brief, the differences are those which result from a low, squat, travelling machine, and the high and somewhat top-

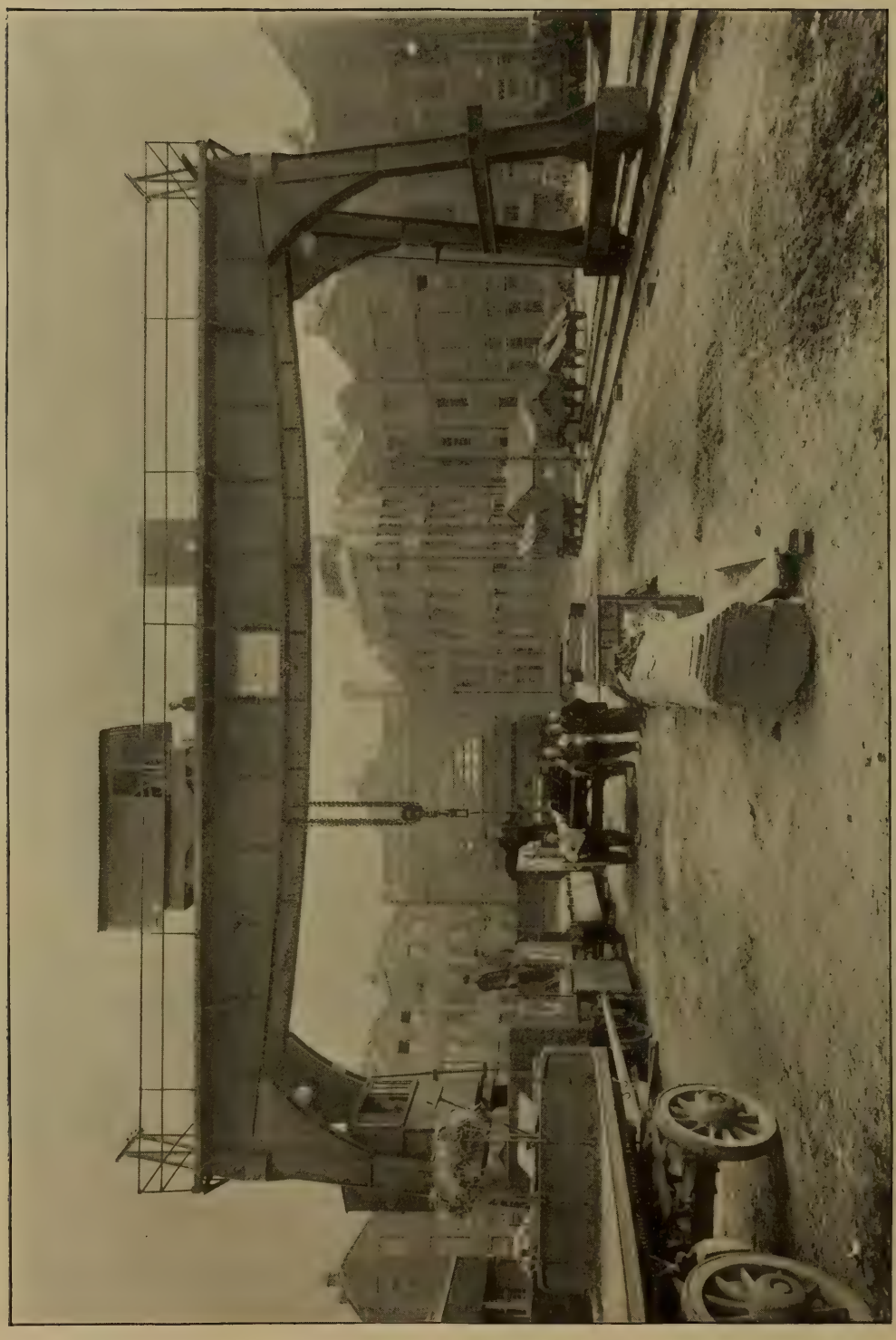
heavy design of the travelling goliath.

The general arrangement of the framing is as follows:—The main girders on which the crab runs, and which are carried on the end frames, are united to them by solid, triangular, or curved gusset brackets, or narrow, diagonal struts which prevent angular movement. Nearly invariably, and always in the older machines, these brackets or struts are placed within the span, the ends of the girders being flush with the outsides of the end-frames. But in many designs the girders are extended, and the gussets placed outside, with the advantage of giving a clear span underneath the girders for the full lifting and traverse of the loads. In several instances the girders are extended yet further to permit of lifting loads a considerable way beyond the end-framings.

The end-frames are always of the *A* type, and are composed of bottom sills, usually formed of horizontal beams, between which pass two verticals and two diagonals, retained in position below by the horizontals, and at the top and about the middle, the whole forming a framing, which, assuming good workmanship, is so well trussed that it cannot in itself be subjected to any serious diagonal working. In some machines the two verticals are omitted. This general type of framework varies widely with differences in goliaths, and prices paid. A wooden framework is still common. It was the first, and for many years the only, kind made, and, provided the timbers are selected carefully, fitted properly with tenons and bolts, and painted at intervals, it is very serviceable, lasting perfectly sound certainly for twenty years or more. Timber is suitable for use in Great Britain and in other temperate climates. An advantage in employing timber abroad, where it can be done, is that it can be fitted with the aid of native labour at less cost



ELECTRIC GANTRY CRANES AT THE COPENHAGEN DOCKS. BUILT BY THE NAGEL & KAEMP IRON WORKS COMPANY, LTD., HAMBURG, GERMANY



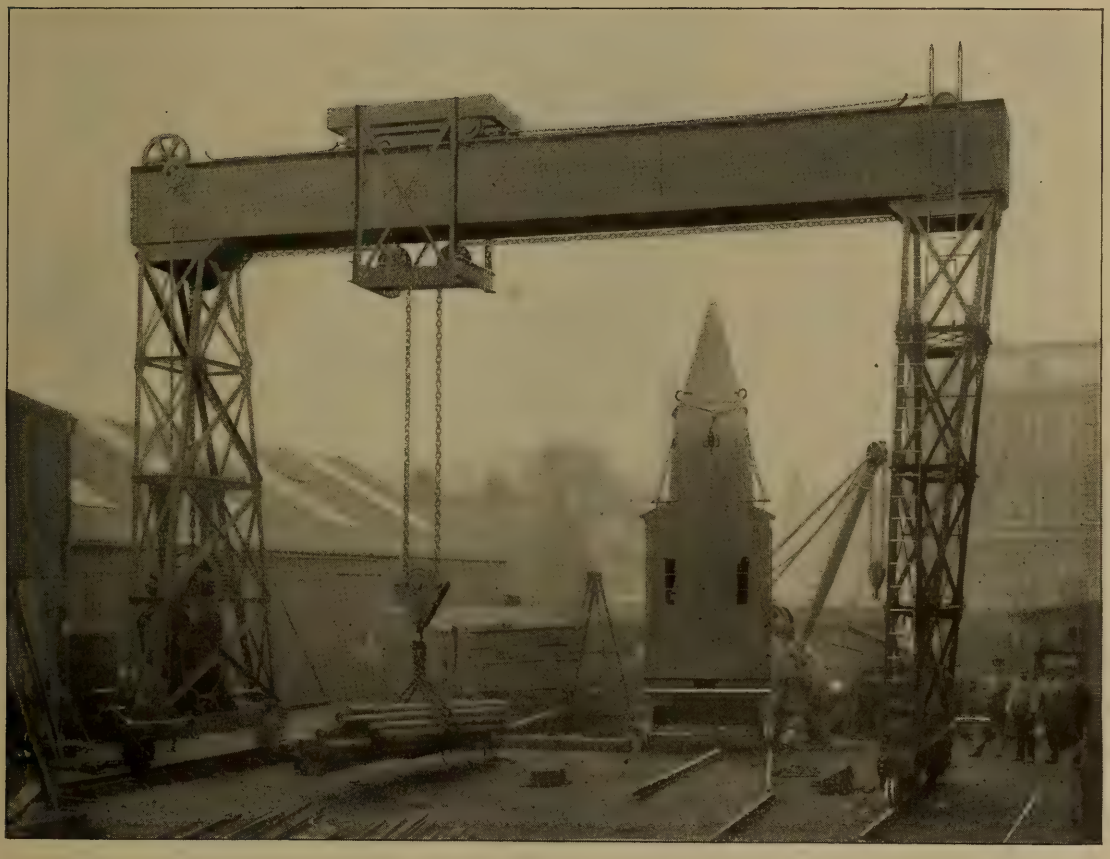
TWENTY-FIVE-TON ELECTRIC GOLIATH USED IN THE CONSTRUCTION OF THE GREAT CENTRAL RAILWAY, LONDON. 60 FEET SPAN, 21 FEET HEAD ROOM. BUILT BY MESSRS. ROYCE, LTD., MANCHESTER, ENGLAND

than either timber or steel work can be sent from home. Many firms, therefore, supply ironwork to customers, who then construct their own timber framings. There is no risk of the timber warping and throwing the bearings and shafts out of truth if it is straight-grained, properly seasoned, and well protected, first with a coat of boiled oil, and afterwards with two or three coats of paint. Deals are not so liable to warp as the hardwoods.

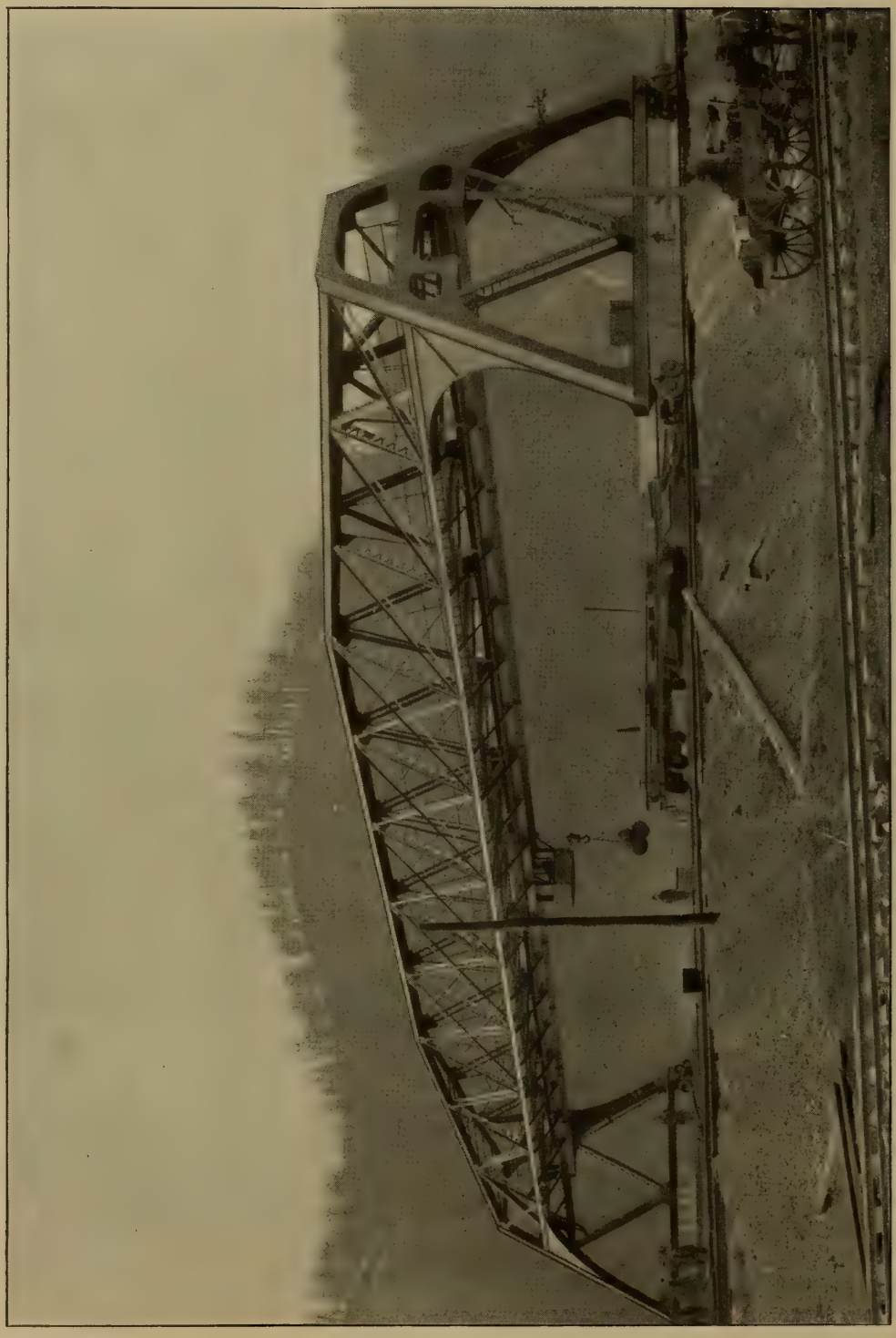
But timber is useless for service in many foreign countries where it is subject to heat and to the ravages of insects. Neither is it suitable for the heavier class of goliaths, though the writer has known a good many of forty tons capacity built of timber. Even for the lighter ones, however, it has rather a clumsy appearance beside iron or steel.

A light and cheap goliath framing is formed chiefly of rolled channel sections, the exceptions being the main girders, which are built up with plate and angle to an *A* section. Gusset plates unite and reinforce the most vital joints; in other parts bolts or rivets suffice. But heavy goliaths which deal with massive loads on broad spans are constructed in a much more solid way, all the girders and legs being of the box type, and the joints stiffened with broad plates. In several instances also end-framings are made double, and connected with bracing.

Goliaths, even in a greater degree than travelling cranes, are subject to stresses that tend to cross-working, because height enters into the case, in addition to span. The most severe test which can be imposed occurs when the maximum load is being carried by the crab at one end, the goliath also travelling along the rails. Such a test puts twisting stresses on the framework that will infallibly find out weak joints, or inadequate proportions in the structure. Hence, the reason of the broad gussets



A HAND-OPERATED GOLIATH CRANE. BUILT BY MESSRS. MENCK & HAMBROCK, HAMBURG, GERMANY



GANTRY CRANE BUILT FOR THE CAMBRIA IRON WORKS, AT JOHNSTOWN, PA., BY THE WELLMAN-SEAVER ENGINEERING CO., CLEVELAND, OHIO, U. S. A.

employed to tie the girders and verticals together. The parallel girders upon which the crab runs have been, in some cases, united at the ends with inner gussets of U shape, built of plates and angles, instead of by plain brackets. In timber frames, and sometimes in those which are steel-plated, horizontal, diagonal struts are fitted outside the main beams to brace them to the tops of the end-framings. Besides attention to these points, a long wheel-base is necessary. The wheels are double-flanged, like those of travellers and crabs, and they are not allowed much side play on the rails. After the observance of these points, if the driving is evenly done, there will be no trouble from cross-working. But apart from these precautions, jamming at cross corners occurs, and, though not dangerous, is troublesome, and liable to fracture the wheel flanges.

The travelling wheels of goliaths have to sustain exceptionally heavy loads. They are made either of cast iron or cast steel, or else with cast-iron or steel centres, and steel tires. The first-named are suitable only for light loads, being lacking both in strength and in endurance of the tread, and the flanges are very liable to be broken off. Cast steel makes good wheels, being strong and wearing well. Such wheels must always be turned on the treads, and only a moderate amount of side play can be allowed between the rails and flanges. These wheels will sustain the heaviest goliaths made. But the alternative to the use of cast steel, namely, the use of iron or steel centres with steel tires, is an excellent one, and is to be preferred for heavy duty. The tires are weldless, being rolled from blanks. They are bored with a shallow recess or check to fit a projecting check on the wheel centre, with a slight allowance for shrinking on hot. No other means of securing them is necessary if the work is well done and the tires are of ample thickness, as they should be. But light tires are apt to work loose, and a stand-by, in the shape of screws, is almost essential if such are to be used. Tires must be turned on their treads. The mounting of wheels on their axles and bearings is a very important detail, because the total loads on these are so great, the net weight of the machine itself, without its load, often exceeding 100 tons, and, in some instances, double this amount. The number of wheels ranges from four to twelve in different cranes, and the load per wheel, at maximum loads, may range anywhere from 5 or 6 tons up to 40 or 50 tons in the most massive cranes made, and under the most unfavourable conditions of loading possible. If the maximum weight be suspended at one end of the gantry it will be carried wholly on one set of wheels, instead of being divided between the two sets. In the case of an overhanging gantry with the load suspended outside, it will be multiplied more by leverage.

How to sustain such loads has been a source of anxiety to crane builders. For heavy block-yard work a growing practice is to have double rails very close together, and the wheel bearing on each with a centre flange between them. Sometimes, as in the 42-ton goliaths working at Dover, the wheels run on double rails, widely separated, each set of wheels under its own frame on a 4-foot 8½-inch gauge. The wheels are, therefore, single-flanged in this case, and there are twelve to each double standard, so that the total load is carried on twenty-four wheels, which works out to about 14 tons on each wheel.

Heavy goliaths also have to be very carefully supported on their wheels through intervening springs. None of the earlier machines were fitted thus, but, as loads increased, springs became essential to easy running. The more uneven the rails, the greater are the advantages of springs. Two are fitted on the lighter machines, four on the heavier. They are generally of the volute form, encircling horns or bosses cast on the top or back face of the bearing blocks, and are retained in shallow recesses in the pedestals which are bolted to the bottom faces of the bottom end-girders. The bearings are controlled in their vertical movements by planed

GOLIATH CRANE, 55 FEET SPAN, 75 FEET HIGH, FOR HANDLING GUN TUBES IN THE WORKS OF MESSRS. VICKERS, SONS & MAXIM, LTD., SHEFFIELD, ENGLAND

guide strips at the ends. Railway sheaf springs also are fitted. A novelty in axle bearings, so far as their application to goliaths is concerned, is embodied in three machines recently supplied by Messrs. Royce & Co., Ltd., Manchester, England, to the Great London Central Railway. All the axles run in roller bearings, and the load of the crane is distributed equally on the travelling wheels by means of compensating levers.

A good many goliaths for service in block-yards have been made with wheels for cross traversing, for transportation to parallel lines of rails. These wheels are carried in bearings the axles of which are movable vertically, so that they can be lifted clear of the cross rails when not in use, and lowered only when required. The elevating screws are controlled by worm gear, operated by hand. In one or two cases this jacking and cross-traversing gear has been operated by power from the crab. By the use of this device the stacking capacity of a yard can be doubled with one goliath. Since these wheels have to carry the dead weight of the goliath only, without the load, they are not so numer-

ous as those which have to sustain the machine when working.

The methods of driving goliath cranes include hand, steam, electric, and hydraulic power. Any one is not absolutely better than the other, but some one method will be preferable under certain conditions, and the choice must be settled by local circumstances. A simple type of hand goliath that does not require constant attendance is that in which the hoisting, racking, and travelling are effected from the ground. When in use, it needs the services of two men, and may require four for heavy loads. Hand travelling gear is placed on each of the two bottom sills, the two sets of gear being identical. Platforms are attached to these girders, on which the men stand when operating the hoisting and the racking gears, the first-named being on one end-frame, the second on both, and each actuating chains or ropes that pass to the carriage, or jenny, on the horizontal beams. Two winch handles are attached to the first-motion shaft of each set of gears, so that for lifting or racking with heavy loads two men can be engaged at each. The trolley carriage, or jenny, is of simple construction, containing two pulleys over which the chain passes in a central bight to the snatch-block and hook suspended below, one end of the chain being anchored. The racking chain is attached to eyes, one at each end of the main bearing. Cast-iron brackets at each end of the main girders carry the various guide pulleys and anchorages. Such a machine as this is not economical for constant service. But for intermittent work it is better than a steam-driven goliath. It is ready for use at any moment, no attendance is required, and no expense is incurred, except during the time when the machine is in actual service. Raw labourers can work it under the directions of

CANTILEVER GANTRY CRANE FOR SHIPBUILDING. SUPPLIED TO THE UNION DRY DOCK CO., AT BUFFALO, NEW YORK, BY THE WELLMAN-SEAVER ENGINEERING CO, OF CLEVELAND, OHIO, U. S. A.

STEAM GANTRY CRANE OF 187-FOOT SPAN. BUILT BY THE BROWN HOISTING MACHINERY COMPANY, OF CLEVELAND, OHIO, FOR THE LORAIN STEEL CO., LORAIN, OHIO, U. S. A.

ANOTHER ONE OF THE BROWN HOISTING MACHINERY COMPANY'S GANTRY CRANES, HANDLING IRON ORE

the man in general charge of the work.

Hand goliaths are made to deal with loads even up to 40 tons where the work is intermittent. But, generally, for the heavier cranes, steam power is employed. The engines and boiler are placed on the crab in most instances, but in some cases to the outside of one of the end-frames, and a trolley only is used for lifting and traversing.

The crab of the steam goliath carries the whole of the gear, as well as engines and boiler for lifting and cross-traversing. Practice is divided as regards the method of arranging the engines on crabs. They are sometimes placed with their cylinders lying parallel with the tracks, sometimes at right angles with them. Which may be the better plan is a matter of opinion. In any case, a to-and-fro vibratory movement is imparted to the goliath framework by the reciprocations of the engines. To reduce this as much as possible, the cylinders are nearly invariably placed at an inclination on the crab framings instead of horizontally, which also permits of a shorter crab.

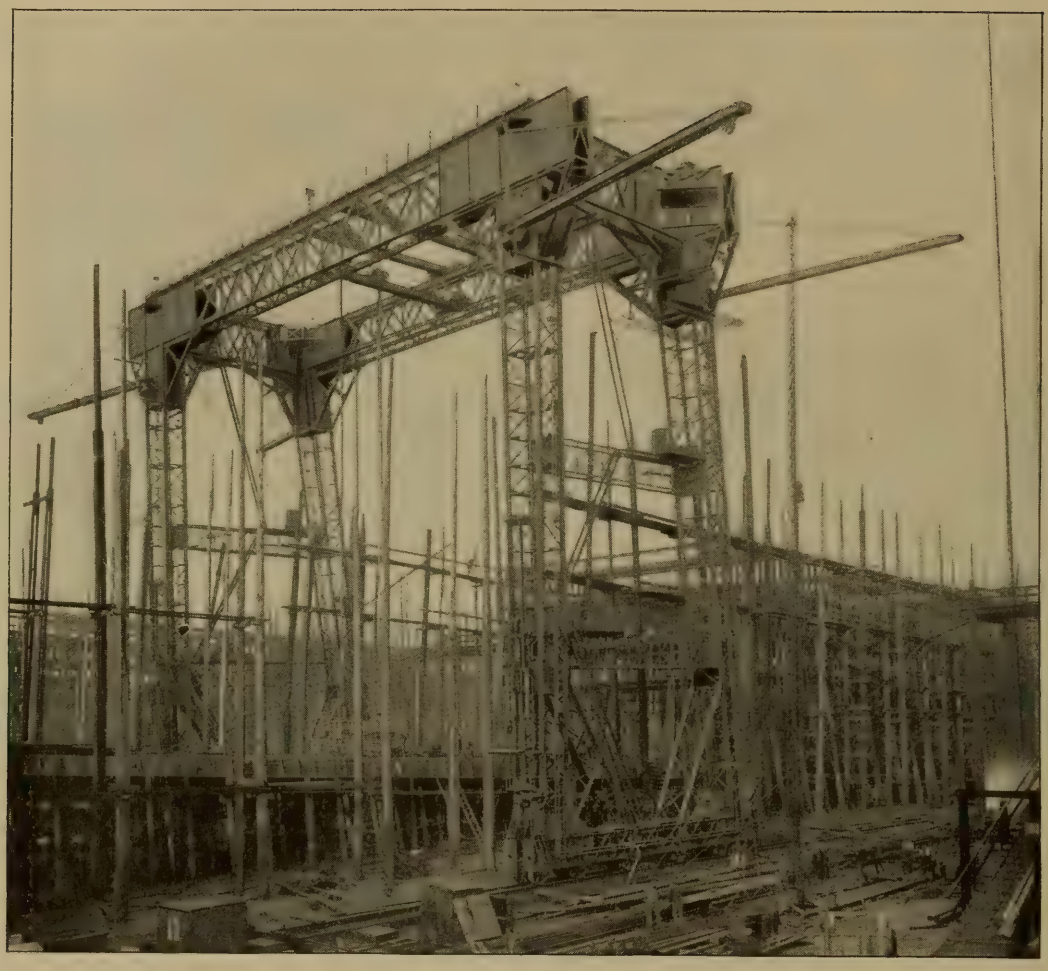
The cheeks of the crabs are either castings, or they are built with steel plates and angles. In the first design the bearings are cast in one with the frames; in the second they are bolted on. Occasionally two crabs are fitted, as in some travellers, and for the same reason, namely, to be used separately or in unison. Wire rope is better than chain for the larger crabs, being more flexible and occupying less room. As there are several parts coming from the barrel to the snatch-block, chains would be very clumsy. Drums are grooved right and left-handed, as in other high-class cranes of large dimensions.

Electric goliaths are properly of the three-motor type. The current is taken from conductors elevated to a fair distance from the ground. If laid close to the ground, they would become a source of danger. If carried very high up, tall and expensive carrier poles would be necessary. The usual practice, therefore, is to arrange the conductors about half the height of the goliath. The motor for the longitudinal travelling motion of the goliaths of Messrs. Royce & Co., Ltd., is carried at the centre of the bridge, driving a shaft whence bevel wheels transmit it to the ground wheel gears. The crab of an electric goliath need scarcely differ from the crab of an electric traveller, so that this section need not be enlarged upon here. Hand gear is fitted to the Royce goliaths to supplement the electrical driving in case of the current giving out.

The travelling movement of goliaths is performed bodily, either through vertical shafts situated outside or inside the end-frames, or by pitch chains. In the first, the shafts are driven by a pair of bevel wheels at the top, and they transmit the movement to a similar pair of bevels at the bottom, which actuate the travelling wheels, the gear arrangements providing the necessary increase in power.

Endless pitch chains are used for the same purpose, and are to be preferred, provided the chains and sprocket wheels are correctly designed and well made. The method of transmission of the power from the movable crab to the travelling wheels through chains is as follows:—A square shaft runs parallel with the gantry beams, being carried in fixed bearings at each end. It is supported at intervals with tumbler bearings, pivoted in brackets attached to one of the gantry beams, the square shaft being turned down at the location of the bearings. A bevel wheel, cast with a long boss, or sleeve, and having a square hole, slides along the shaft. It is in constant engagement with a bevel wheel on the crab shaft, and is driven by it. Whatever the position of the crab, therefore, the latter will drive the square shaft, and thence the travelling gear below, by throwing in the clutch provided for that purpose.

To produce equal driving power at both ends of the goliath, the drive must be duplicated. A sprocket wheel at each end, therefore, of the square shaft drives to a sprocket that has its bearing on the bottom sill of the uprights, and thence spur gears transmit motion to the travelling wheels.



THE GANTRY CRANE USED IN BUILDING THE WHITE STAR LINE STEAMER "OCEANIC," CONSTRUCTED BY MESSRS. FIELDING & PLATT, LTD., GLOUCESTER, ENGLAND

The strain on either type of driving gear,—bevel gears, or pitch chains,—is severe. Each gives good or bad results, according to the proportioning and the fitting. Teeth of wheels will break unless their bearing brackets are well supported. It is not enough to bolt them merely to the plated work. The latter must be stiffened with diaphragms or brackets, or else the wheel bearings will spring under the strain and cause the teeth to fall partially out of mesh and to fracture. Another method is to cast a double bearing to support the outer end of the travelling wheel axle, and to prevent any relative movement occurring between that and the vertical shaft. Pitch chains, to give satisfaction, must have wheels pitched carefully and teeth designed correctly, and the bearings must be rigid. The best pitch chains are those in which the links, instead of being in one piece, are built in several thicknesses. Every piece must be machined to gauge, and all holes and pins case-hardened.

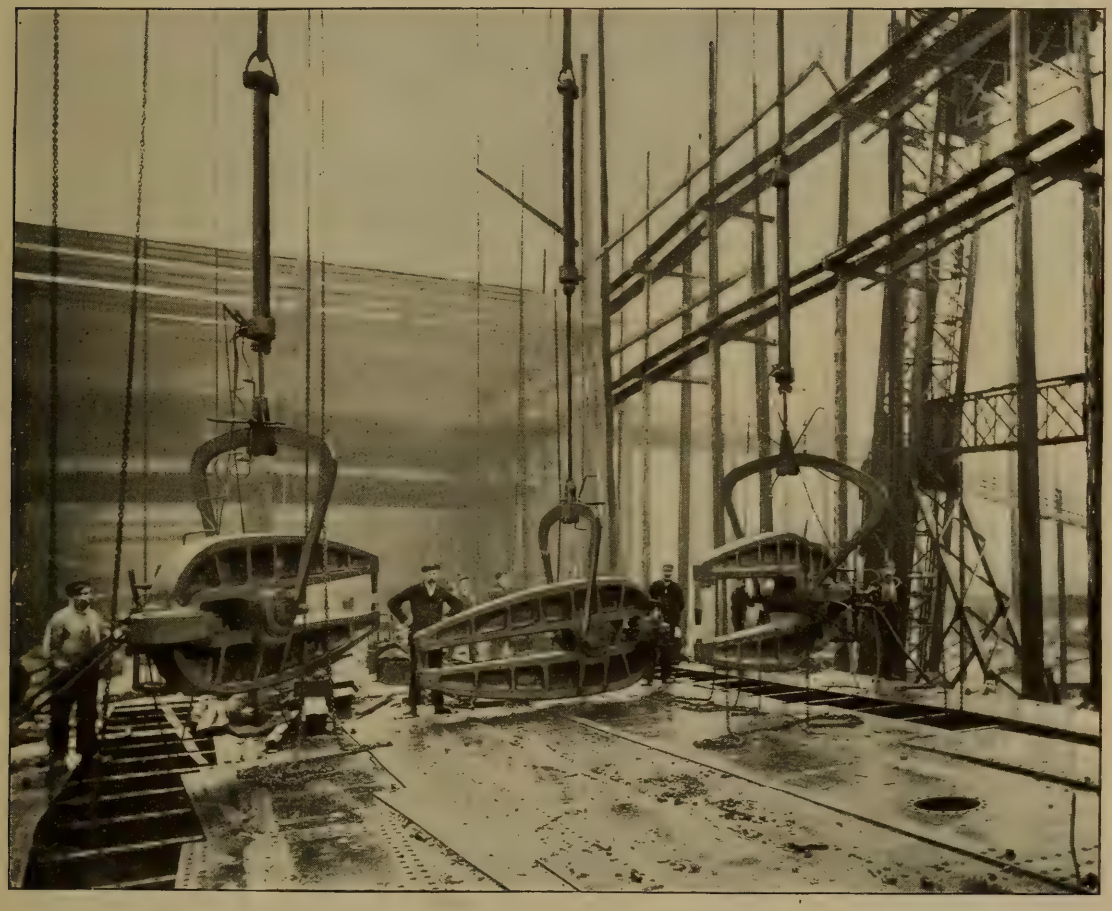
A platform and hand rail are fitted to goliaths, supported in angle brackets, attached to one or to both the main girders. An iron ladder must be provided for getting from the ground to the platform and crab. Stiff wire brushes are sometimes attached to the ends of the bottom sills of the end-framings to sweep away small stones and other obstructions from the rails.

Some of the special applications and utilities of these cranes may now be noted. Goliaths fulfill important services in harbour work, being commonly used for lifting concrete blocks, previously made in the block-yard, on to their trucks for transportation to the gantry, or the Titan crane. As the loads are great, often 40 tons or more in weight, the design of these goliaths is more

massive than that of the ordinary types. The scantlings are built up with plates and angles, and large gussets are worked in to form an integral part of the structure. The inner brackets are often a part of the framework, being riveted in with curved outlines, instead of angles, to give stiffness without interfering with head room. The bottom sills of the end-framings are frequently of a boxed form, even though the verticals and diagonals are of single-webbed type. Each member is of the same width or

out either a travelling crab or trolley, the hoisting tackle being fixed on the gantry beams. Loads of 40 and 45 tons have been handled in this way on spans of 11 feet and less.

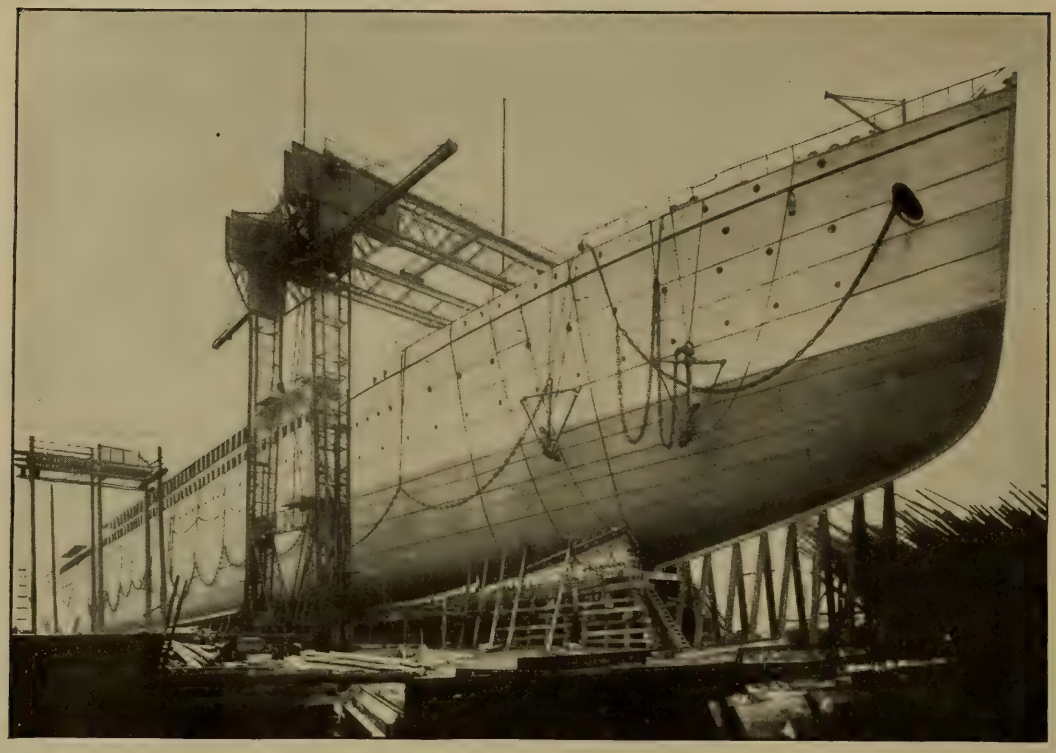
When blocks have to be loaded into barges to be transported by water, goliaths have been constructed to extend partly over the water. In one example of work at the Sulina mouth of the Danube, one of the uprights ran on rails on the land, and the other on rails carried on piles in the river. The newly-



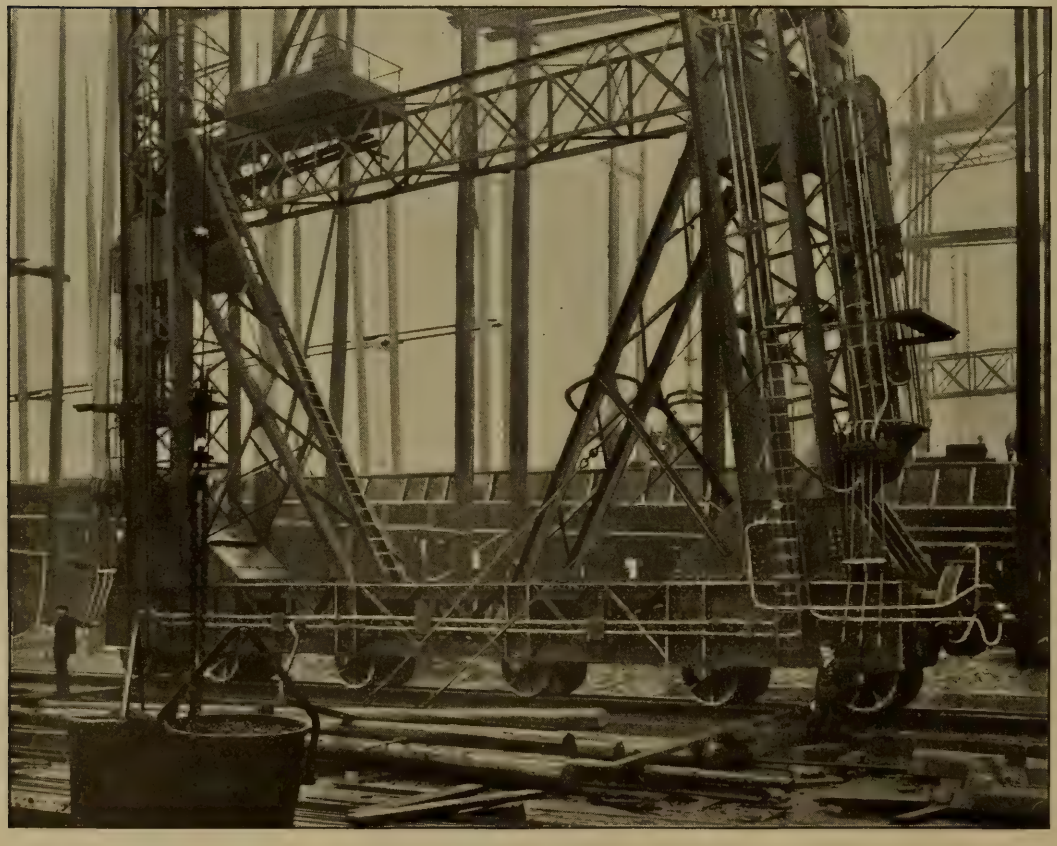
HYDRAULIC RIVETING MACHINES SHOWN SUSPENDED FROM THE GANTRY IN BUILDING THE "OCEANIC"

thickness, to present flush faces for the riveting on of broad covering or gusset plates. The spans of these vary to a considerable extent, but fifty feet is a usual one. The advantage of a wide span is that more blocks can be stacked in the width without extending the length of the yard excessively. In a few cases goliaths of very small span for block-yard work have been made, with-

made blocks were lifted by the goliath and deposited on the landward side, and, when dried, were picked up and traversed by the crab to the barges in the stream adjacent, and there deposited. The same result is attained in a better and less costly way by extending the gantry beams beyond the uprights in cantilever fashion. From this point of view the double cantilever



THE "OCEANIC" IS HERE SHOWN READY FOR LAUNCHING AT THE YARD OF MESSRS. HARLAND & WOLFF, BELFAST, IRELAND



VIEW SHOWING BASE, HYDRAULIC ENGINES AND CRANE CYLINDERS OF THE TRAVELLING GANTRY

cranes of the Brown Hoisting Machinery Company, of Cleveland, Ohio, U. S. A., may be regarded as goliaths of an exaggerated and very special type.

A goliath used at the Sheffield works of Messrs. Vickers, Sons & Maxim, Ltd., for shrinking jackets around wire-wound gun tubes, lifts 100 tons. It is remarkable by reason of its abnormal height, 75 feet, with a span of 55 feet. The lift, though so high, requires multiplying gear to transmit the stroke of the hydraulic ram, which actuates the load, to the snatch-block, with its lift of 67 feet. There are eight bights of 1½-inch chain, with a total length of about 2500 feet. The chain is suspended from a trolley, the traversing motion of which is actuated by an engine. A similar engine performs the travelling motion. The trolley runs on eight wheels on four lines of rails, arranged in pairs, 20 inches apart, on the bridge girders. The goliath is carried on eight wheels, the bearings of which are pivoted to accommodate themselves to wear or unevenness. A view of this crane is given on page 144.

Some of the massive goliaths at Dover Harbour have a span of 100 feet, with a clear headway of 25 feet, and the machines weigh 216 tons each. One of the largest span goliaths yet made, namely, 200 feet, is that of the Cambria Iron Company, at Johnstown, Pa., U. S. A., constructed by the Wellman-Seaver Engineering Company, of Cleveland, Ohio. It is interesting from the fact that the trolley is suspended on the bridge tracks, and that the Pratt girders, of which the bridge is built, are inclined at an angle of 60 degrees to each other, making, in cross section, a triangular structure. The goliath is carried on wheels, the pressure of which is taken on hardened steel balls and sockets. These have a slight amount of play to permit of expansion of the bridge by changes in temperature, and of a slight degree of cross-working of the framing. The cupped groove in which the balls fit is slightly elongated in the direction in which the girders would expand. The goliath is travelled at a speed of 200 feet per minute by a 50 H. P. electric motor placed at the centre. The trolley is traversed at 400 feet per minute, and the load hoisted at 20 feet, each with a separate motor of 25 H. P. This crane is shown on page 142.

Some of the Brown Hoisting Machinery Company's goliath (gantry) cranes are of immense span, some at the Carnegie Steel Company's works measuring 232 and 236 feet, for loads of 7 and 5 tons. The light, trussed beams, the lattice-braced uprights, and the mobile trolleys differ in almost all details from the heavy British types. A goliath crane by Messrs. Menck & Hambrock, of Hamburg, Germany, has the rather exceptional design of a single, solid, boxed girder on which the trolley travels, and from which suspended hangers carry chain pulleys that lead to the snatch-block as shown on page 141.

There is a special form of goliath for block-yard use in which the blocks are lifted by screws and nuts, operated by worm gearing driven by an engine, the lift being just sufficient to pick up a block and place it on a truck, which, in this case, may run on a track below the level of the ground. For the erection of massive work in engineers' yards the goliath is the most serviceable machine that can be used. It can be made of any height or span to suit the nature of the work in hand.

The speeds of goliaths are not so high as those of travellers. Those of the 42 tons load at Dover are,—travelling, 60 feet per minute; traverse of crab, 50 feet; lifting, 10 feet per minute. The three 25-ton machines made by Messrs. Royce, Ltd., for the Great Central Railway, in London, have travelling and traversing speeds of 50 feet per minute.

Goliaths are sometimes made that form a connecting link between the goliaths proper and the gantry cranes, —that is, a gantry with a jib crane on it. Thus, for shipbuilding, one of the Sellers cranes of 5 tons capacity has a crab traversing the bridge, and a cantilever crane suspended out from one end. The height in this case is 70 feet, with a span of 51 feet, and the driving is by

three motors. But the most remarkable machine of this composite type in existence was erected at Messrs. Harland & Wolff's shipyard, specially for the building of the White Star Line steamer *Oceanic*. The clear height is 98 feet, and the span 95 feet. It carries three travelling cranes on the bridges, and a jib crane at each corner. The latter are used mostly for lifting the plates, the former for sustaining the portable riveters. Hydraulic power actuates the travelling and other motions. The rails are double, twenty-four wheels in all supporting and travelling the crane. This crane was built by Messrs. Fielding & Platt, Ltd., of Gloucester, England. Illustrations of it are given on pages 148 and 150.

The goliath occupies a position which cannot be filled by any other type. A portable crane running on rails is a makeshift in a yard, the whole area of which has to be covered. Objections to its use are, occupation of a portion of the ground by the crane and its track, the time required for slewing the jib, a more inconvenient operation than the traverse of a crab, and chiefly the awkwardness of lifting loads to one side of the rails, which, in the case of maximum loads, can be effected only by the employment of rail clips, or blocking girders. The only alternative to these is heavy and somewhat risky counterbalancing, which requires very steady and careful working on the part of the driver to prevent surging backwards and overturning. Or there remains the use of a wide gauge of 6 or 7 feet in place of the standard one,—a device which interferes with the movement of the crane on to standard tracks.

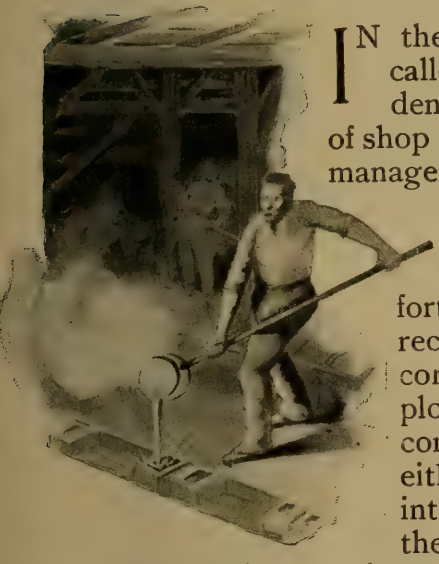
These drawbacks put the jib crane completely out of competition with the goliath for doing work of the kind named. The only rival, in fact, of the goliath for yard work is the overhead traveller,—its nearest related type—in which case a stiff gantry of timber or iron is erected on piles driven into the ground, the gantry being long enough and of sufficient width to flank the yard area that has to be covered. The traveller runs on this raised gantry as it would run on that in a shop. This is a very good arrangement, and one to be recommended where the nature of the work is such that the fixture will be a permanent one. It is very common in builders' and contractors' yards, where heavy timber is framed together, and in the yards of quarrymen and masons where stone dressing is always going on. For many classes of work the presence of the permanent gantries would be objectionable; in others, the outlay would be warranted. For temporary service the self-contained goliath is preferable.

INDUSTRIAL BETTERMENT

IN THE IRON AND STEEL INDUSTRY

By H. F. J. Porter, of the Bethlehem Steel Company, South Bethlehem, Pa.

Mr. Porter's contribution is an interesting supplement to the opening article in this issue by Dr. Tolman. While altruistic measures are commended by Mr. Porter, he lays preponderating stress upon the satisfactory adjustment of the wage scale as the one thing without which all other measures for the benefit of the workman are unlikely to achieve their object.—THE EDITOR.



IN these days of so-called altruistic tendencies in methods of shop organisation and management, we are apt to compare the unusual conveniences and comforts which have recently been accorded to the employees of different concerns, without either fully taking into consideration the reasons for their introduction or investigating the results of their operation. But so different are the conditions under which the various industries are operated, and so varied the environments and necessities of the employees in each enterprise in those industries, that a careful inquiry should be made before passing judgment upon those concerns which, to the casual observer, have not followed closely along lines which are now considered altruistic.

In the iron and steel industry the labour problem has been a disturbing one from medieval times. In those early days it was an art to smelt and forge the raw materials and manufacture them into finished products. The artisans who performed the different operations organised themselves into guilds which were as close corporations as ever existed. Those were the days when men held their trade secrets as their capital, and divulged them only to their children or lineal descendants and to a few apprentices who, under penalty of death, were forbidden to disclose what they had learned.

Under such conditions there was no progress in the arts except in the direction of hand skill. Men depended for their bodily safety upon personal armament, and the noble robber barons of the times employed swordsmith and armourer for months and sometimes years on single pieces of work, the artistic beauty of which has never been surpassed. The Church, working upon the superstition of the people, vied with the barons in wealth and put enormous sums in the building of cathedrals and monastical establishments, the decorative features of which were largely enhanced by the handiwork of the ironsmith.

Those were the dark ages when ignorance was the father of intolerance. But with the light of science breaking through the darkness of the times, the knowledge of the metallurgy and chemistry of iron and steel became disseminated, and technically educated men forced their way into the industry, tending to change it from an art to a science. Then the allied guilds, feeling the attack of intelligence upon their domain, used their only weapon of defence,—the strike,—and followed it up by force where necessary. Retaliation and resentment on the part of the employer brought about the lockout, and, through hereditary inability to break away from precedents established by their medieval antecedents, the trades unions and the

capitalists have preserved to us to this day this species of barbaric warfare, and it is a disgrace to the intelligence of our nineteenth and twentieth centuries that it is so.

Social psychologists tell us that the impulse to kill is one of the most primitive and basal in the long years of struggle to survive, and that it is only now modified by civilisation to a desire to overcome and hold the subordinated in subjection. This feeling, as it shows itself among the most enlightened, Herbert Spencer terms the "bias of class." It is this very social inequality which so many of the unthinking decry as a misfortune that lies at the foundation of all advance in civilisation. This feeling and the tendency to adhere to precedent have retarded progress toward the adoption of methods of government that might be more humane and show a feeling of broader tolerance.

But the vital forces of the world are moving in unison toward the uplifting of mankind; the awakened spirit of the present recognises this to be the unceasing purpose that runs through the ages and that the manner in which a man fulfills his duty to his neighbour is a gauge of his intelligence and character.

The narrow religion of a few years ago taught us that the adherence to a creed or dogma was the sole essential to salvation. A broader interpretation of sacred writings shows us that the aim of all religions, when stripped of form and ceremonial, is to encourage man to uplift his fellows. Social science teaches us to do this, not by indiscriminate charity, but by showing men how to help themselves, and lending a helping hand where necessary, and in our business world we are now learning the best methods of carrying out this policy. Each industry and each enterprise in that industry must determine how best to do this for itself, and the iron and steel industry, having to overcome opposing precedents born of long-established usage, must be governed accordingly.

In the larger enterprises of the iron and steel industry are employed thousands of men of various types of intelligence, from the ignorant foreign labourer upward. Labourers are generally paid by the day, a standard wage-rate being established for each character of work. Thus the old and young, the weak and the strong, irrespective of the amount of work performed by each, all receive the same amount per day, provided they are engaged at the same kind of work. Men engaged in turning out special lines of product, work in gangs and are paid by the ton, the pay being divided equally among them. But a chain being no stronger than its weakest link, the capacity, and, therefore, the pay of a gang, is affected by the mental and physical characteristics of its individual members. The average wage rate of each individual in a gang is, therefore, lowered by conditions entirely beyond the control of that individual.

These methods are evidently unfair and conducive to discontent among the men, and in the past have been the cause of dissatisfaction to both employer and employee. Yet this is the system which the trades union is still directing its endeavours to maintain, on the principle that all men are equally capable, and, if employed on the same class of work, shall be paid alike. But it is evident that any system under which both the competent and incompetent are placed in the same category will deaden personal ambition, and where this element is wanting there is no advance.

Management of men has now become a science in itself; its principles have been worked out from an analysis of past successes and failures. It now behooves both employer and employee to study the recommendations of the social scientist that both may work together for their common welfare, for it must be evident to the veriest tyro in his investigation that the interests of these two classes of men are not antagonistic, and that in any enterprise a house divided against itself must fall.

Huxley says that there are two opposing methods of government in the world, respectively, the cosmic and the

ethical. One aims directly at securing a survival of the fittest, while the other tends rather to encourage as many as possible to survive. A scientific, but conscientious, system of management, based on a combination of these two methods is sure to bring about a result which will be fair and satisfactory to both employer and employee. A system of management which succeeds in obtaining the best of a man's labour by paying for it, has long been proven to be superior to an effort to obtain something for as little as possible, "for," the saying was trite twenty centuries ago, "the labourer is worthy of his hire." The employer must feel that the question is not, what salary must I pay, but, what ought I to pay?

It is plainly the duty of the intelligent employer to institute a system of payments by which each individual shall be paid according to his merits. Much time and careful observation must be directed to the establishment of a fair day's work for the normal man, as well as the rate of payment for it, and a generous bonus should be given to all who exceed the stated amount of work. To bring this about, however, requires much skill and patience, a kind and generous nature, and a sound judgment. A wage rate, once established, must not be changed whether the times are good or bad, otherwise the men become disheartened, fearing a cut in their pay.

By this means those who are by nature best fitted for a special type of work are stimulated to exertion, for they know that the more they accomplish, the higher will be their daily wages. They are not held back from receiving the full amount to which their capabilities entitle them from the fact that there are others in the same gang who either cannot or will not work as hard as they. After a while the men of the latter class drop out and are replaced by others better fitted for the kind of work in question. Those who drop out must receive the special consideration of the employer and be given an opportunity to work at other employment better suited to their tastes or capabilities. They may have been examples of a system attempting to fit a square peg into a round hole. Those who find suitable occupation should be encouraged by fair wages to excel in it. Drones who do not want to work drop out for good. They are a disturbing element in any system of management. A place once earned by a man must not be forfeited by favouritism, or the confidence of those remaining will be lost. There is nothing so conducive to a man's peace of mind as the knowledge that his occupation is steady and his income sure.

Following out this policy, a conscientious and efficient clerk should, from time to time, have his salary raised voluntarily by his employer. By this means an inducement is offered to confine his attentions to his duties rather than have it dissipated by efforts to secure another position which, he may feel, would compensate him better. Many a concern has lost valuable men by being dilatory in awarding them what they were entitled to.

Encouragement should be given to the establishment among the men of a beneficial association, in which the employer should furnish more than half the dues. The benefits accorded to members in such an association should include not only financial support in time of temporary illness, and similar assistance in case of death, but should include also a moderate pension in case of total disability from sickness or old age. The privileges of membership in this association should carry with them the services of a capable male physician and female nurse. These latter should be selected not only for their wide experience, but for their genial and sympathetic nature. Such attendants, regularly visiting the homes of the employees, aid greatly in promoting their health and happiness, and in raising the percentage of daily attendance in the shops.

Once the ambition of the men is aroused and their confidence in the justice and fairness of a system has been established, the success of an enterprise is assured. The ability to make better

wages than can be obtained in the market for ordinary day labour will draw to an employer an intelligent and capable body of men who cannot be cajoled by the reasoning of the demagogue who urges them to strike because others are not getting as high wages as they.

Trades unions which, under intelligent leadership, would wield a mighty power for advance, are now conducted on the theory that all men are equally capable, and as long as their fundamental principle is false they cannot succeed. Such organisations benefit only the incompetent, and them but temporarily. The capable ones are able to care for themselves without such assistance if only the opportunity is afforded them.

The wage scale having been fairly adjusted, the employer need not worry himself about what altruistic measures he will adopt for the benefit of his employees. Once the interest of the latter in the success of the enterprise becomes established, suggestions regarding methods which will be to the common interest of employer and employee will come fast enough from the men. Conveniences which good men need to do their work well and keep them in prime condition, mentally and physically, are of advantage, and they are bound to come. But they have their time and place of coming, which are after more important things are settled. It must be remembered that kind words, and rest rooms, and libraries, and lectures, and other so-called altruistic measures, although excellent in their proper time and place, do not in themselves bring happiness and contentment, for they do not supply food, and clothes, and house rent, and home comforts, and the latter are what men work for. Of such things, therefore, until the proper time arrives, the men become suspicious, as they partake of the nature of charity, and honest workmen resent anything of such a nature. The men must be mentally happy and well advanced in modern thought and methods before such things can be introduced

Nor should an employer allow the announcement to become current that he has a "model shop" when he has made his business a success by adopting the methods outlined above, and added such conveniences as he finds are of common advantage to his business and his men. Intelligent workmen are sensitive to being referred to as adjuncts to anything "model."

An attempt to advertise an enterprise by proclaiming that philanthropic principles dominate its management may be effective for a time, but men lose respect for such philanthropy and its projectors. There is no philanthropy about it; it is pure business. Nor should a manager announce to his men or to the public that he incorporates advanced ideas in his system of management "because it pays." No advantage can be gained by such a course. It will, in fact, be found that it does not pay. He should no more think of making such a statement than of saying that he keeps his own hands and face clean or changes his linen daily "because it pays." The employer must be a philosopher, but it is not his province to impart his philosophy to his men or to the public. By his philosophy he must give life to his business.

It is the providence of the expert in social science to analyse methods and systems and impart his findings to embryo employers and employees from the forum of the school and the university, and to active men of affairs by means of his literature and reports. It is the duty of employers to study carefully the science of management of men and to adopt its principles in their business. It is, above all, the duty of the employed, and especially of those who are selected to represent the interests of their fellows at councils of the trades unions, to familiarise themselves with the general principles of industrial success in order to meet the employer on a common platform. The time has come when intelligence wins. Ignorance, backed by force, no longer has any standing in the councils of those who are indoctrinated in methods which are successful because they are scientifically true.

AMERICAN AND BRITISH ROLLING MILL PRACTICE

WHY AMERICAN COMPETITION IS SUCCESSFUL

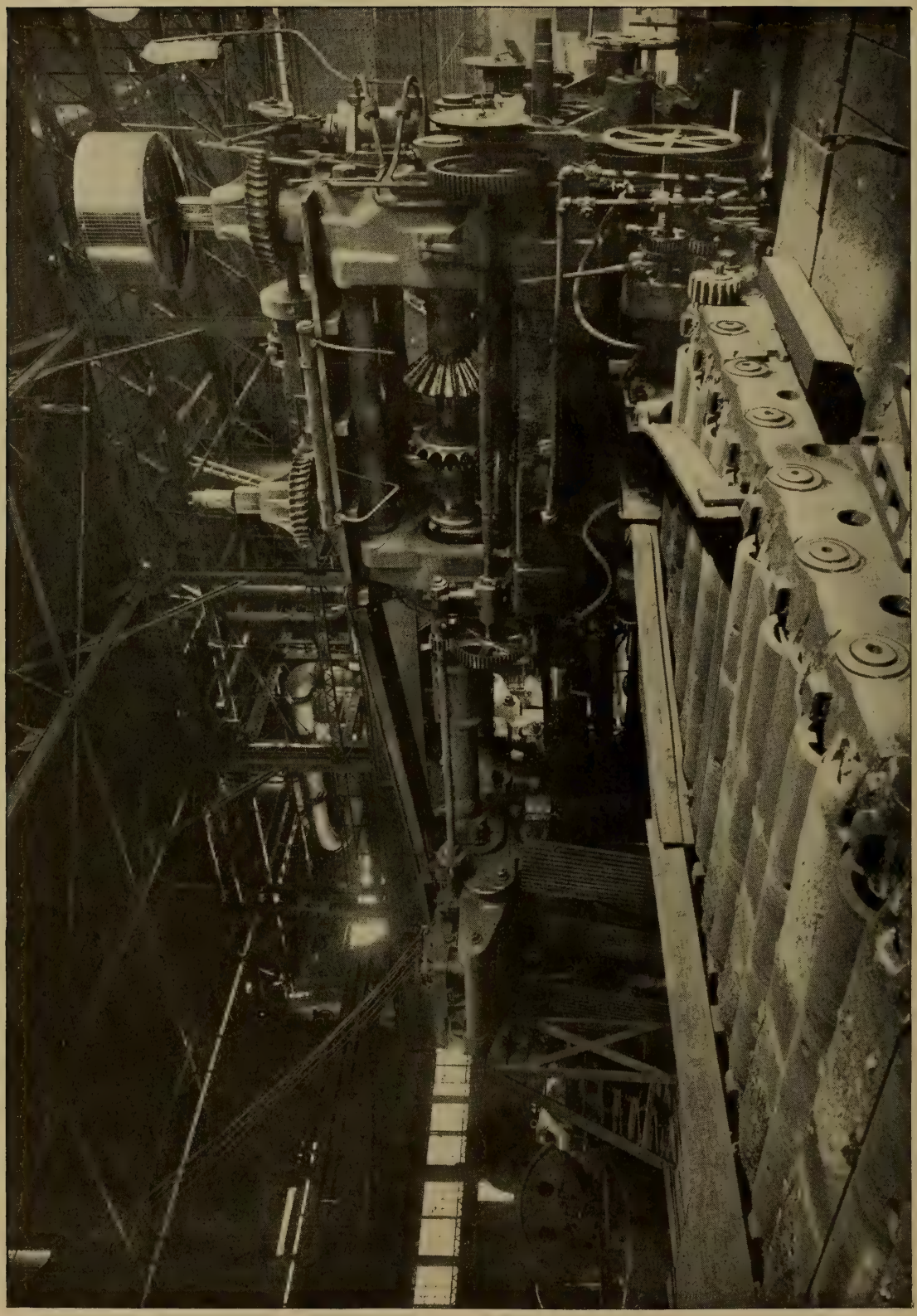
By William Garrett

Mr. Garrett's remarks, as given in the following pages, represent practically in full his paper read last month before the Iron and Steel Institute, and have been reprinted here particularly because of their bearing on that present bugbear to the British manufacturer,—American competition. Mr. Garrett wrote from the standpoint, altogether, of an American, addressing the British maker of iron and steel, and endeavoured to show where, and to what extent, his methods fall short of present requirements of industrial success by contrasting them with current rolling mill practice in the United States.—THE EDITOR.

GREAT BRITAIN is not only mistress of the seas in times of war, but also in times of peace. Her ships are found on every sea,—on every shore,—in every clime. Her means for reaching foreign countries are unequalled by any, and this, combined with her past wonderful resources in the way of fuel and iron ore, and the fact that Britain was the home of a Cort, a Bessemer, a Mushet, a Siemens, a Thomas, a Gilchrist, and a Lowthian Bell,—the achievement of every one of whom in their day and generation has marked an era in the manufacture of iron and steel,—all this is what gave Great Britain industrial supremacy. There were, first, the raw materials; second, the markets; and third, the brains. But in the course of time conditions have changed. The fact that coal is being delivered in Newcastle as it were, or material is being delivered at the door of those who at one time controlled the manufacture of this material, proves this to be the case.

This being so, what are the conditions that have changed? Lack of raw material? It appears not, for Great Britain is the second largest producer of coal in the world, the output for 1898 having been 220,085,303 tons, and both Sir Lowthian Bell and Mr. C. Kirchhoff are trying to outvie each other in proving that pig iron,—the base of iron and steel,—can be manufactured in Great Britain as cheaply as anywhere in the United States, taking into consideration the long haul necessary to bring together the raw materials necessary to make pig iron in the United States. Sir Lowthian Bell is very skeptical as to the possibility of any foreign country being able to land iron or steel on British shores in competition with British manufacturers, believing that the many thousands of miles over which the iron and steel have to be transported is a barrier never to be overcome.

As to Great Britain's supremacy on the seas, and the accessibility to her of her foreign markets, no one for a moment believes that there ever was a time when she was better able to reach any part of the world than at present, and new markets are being opened up every day. What does the trouble in China and the Transvaal war mean? In the end, more markets, not only for British products, but for the products of the whole manufacturing world. Since it is not because you cannot make your pig iron as cheaply as it is made elsewhere, and not because of the curtailment of your markets, and cannot be because of your ignorance of scientific truths, what can be the reason why you are underbid in regard to rail contracts for abroad; for tin plate bars, shipped by thousands of tons right into your tin plate district; for thousands of tons of soft steel billets, delivered to your rod mills and merchant mills; thousands of tons of plates, delivered right at the back door of many of your steel plate makers; and skelp and strips for making pipe and tube are landed next door to your manufacturers of strips. It would seem that all the blame lies with the men who start with the pig iron and put it into the finished material.



FORTY-EIGHT-INCH MILL ROLLS AND ENGINE AT THE CARNEGIE STEEL COMPANY'S WORKS

But before going into this question, just think for a moment what it means for the Pittsburgh manufacturer to deliver his product in England or Scotland. It means that he has to ship his material over 3000 miles by water and nearly 500 miles by land, at a cost of between $5 and $6 per ton, or about 25sh., and, all things being equal by way of manufacture in both countries, it means that the Pittsburgh manufacturer should have to get his ore and coke for nothing in order to be able to do this. It cannot, therefore, be all on account of the advantage that the manufacturer of the United States has in regard to cheaper raw material. To come to the point, where does this difference in the cost of manufacture come in, assuming that we are already agreed,—which we have on the best of authority,—that Great Britain can produce pig iron as cheaply as the United States? During the period of 1893 to 1896 many thousands of tons of Bessemer pig iron were sold for $9, and 4-inch billets could be bought in the open market at that time for $14 per ton, a difference of $5, or 21sh., per ton; so you must be able to convert pig iron to steel billets for less than that amount, for some steel makers at that time paid a dividend. If not, then there is something wrong with your method of making Bessemer steel ingots and rolling them into billets.

BLOOMING MILLS

As my remarks are to be confined to rolling mill practice, I will begin my comparison with the blooming or cogging mill. I understand Great Britain to be the birthplace of the Ramsbottom reversing engines and reversing blooming mills. America, in its early history of making Bessemer steel, adopted the three-high roll system, and no two men have done more to perfect this system than Mr. John Fritz and his brother, George. But since the advent of the 4-inch billet which is now so universally used in the United States, the two-high reversing mills have become almost universal, except for rail-mill purposes. We simply copied what you had already done, and improved on your work. The reason why a three-high mill is not considered so well adapted to make 4-inch billets is that when, as is often the case, a 6000-pound ingot is used, the piece would be over 125 feet long when finished to a 4-inch billet, and the lifting tables would have to be very long, in fact, too long to be conveniently handled; so, with the exception of one or two mills which make some product other than billets, all 4-inch billets are made on two-high reversing mills.

Logically, no other country should have been ahead of Great Britain in adopting the 4-inch billet as the standard size, while the fact is, that no country is more prejudiced against it. I will endeavour to state why. All of your blooming mills are attached to finishing mills upon which you make rails, structural shapes, large merchant bars, and small billets. Owing to this diversity of product from one mill, there is necessarily a great deal of roll changing, and, when changing rolls, the whole system is stopped, up to the making of Bessemer steel,—everything standing still, time lost, money lost, and plant non-productive. In some places duplicate finishing mills are used in order to prevent this loss. If your cogging mills were adapted to make 4-inch billets, the same as in the United States, and your small merchant and rod mills adapted to take a 4-inch billet, all this loss would be obviated and the expense for an extra mill would be unnecessary, as you could be making 4-inch billets while changing rolls. In order to make, say, a 2-inch billet, you must go through nearly all the motions of making a rail, except straightening, drilling, etc., must use the whole train and the same number of men, and a 2-inch billet costs nearly as much to make as angle bars. You should also be able to roll slabs suitable for making light plates, but you roll nothing but blooms suitable for the finished material your finishing mill is adapted for. All that is necessary to make a 4-inch billet and slabs, and any size of bloom for rails, for example, is a pair of rolls exactly the same as in general use on a blooming mill in the

United States, with the necessary room for shearing and taking care of the billets.

That it is desirable to find a market for what sizes you can make on your blooming mill while changing rolls is evident, seeing that your German competitors have recently adapted themselves to take a 5-inch square billet, which they roll at one heat into wire rods; in fact, in some places they take a 6-inch or 7-inch bloom and roll it into rods at the one heat. These blooms are sold at a reduced rate from a 2-inch billet, as they are able to make those sizes on their blooming mill while changing rolls.

This is leakage No. 1,—adding to the cost of all the material you make on your reversing blooming mills. Next is the time lost on account of the irregular way in which you keep your mill filled up with material. In America, the greatest effort is made to find something for the blooming mill to do while changing rolls, and to keep the mill continually full of material. It is an acknowledged fact in regard to American mills that stoppages from breakages or some unseen cause are considered a misfortune by the management. Time lost through not keeping the mill full is considered a crime, and results in the immediate dismissal of the responsible party. Go to the manager's office in connection with any well-established steel plant and you will see on record a statement of what has been done in every department during every hour of that day, and the cause for every minute of lost time, if any. But it may be said by some that, owing to close attention to this point, the American mills and engines are better constructed than those in Great Britain to stand this,—you may say,—undue pressure. I may say here that the blooming mill holding the world's record for the production of 4-inch billets per twenty-four hours, having produced 1260 gross tons in that time, at the plant of the Lorain Steel Company, at Lorain, Ohio, from an 18″ × 20″ ingot weighing 5500 pounds, is driven by a Galloway engine, and, in justice to the British engine builder, I may add that no engines in the United States give better satisfaction than the three Galloway engines at the plant of the Lorain Steel Company.

RAIL MILLS

We will now briefly consider your rail mills. Why is it that you do not make a larger tonnage on them? Is it because you do not desire to? If this be the case, I have nothing further to say on that point. However, if the reply be that you cannot find a market for any more tonnage, then I will ask why do American manufacturers ship so many thousand tons of rails to the foreign markets that were once yours, and underbid you to get orders? Why is it that you are making rails in every two-high reversing mill in your country, and, in doing that, are not only losing your orders for rails, but allowing thousands of tons of tin-plate bars to come into your tin-plate districts, whereas, if you could produce more rails in a given time, you would have more time to make tin-plate bars. And if your rail mills are not so well adapted as they ought to be for making rails or tin-plate bars, is it not better to remedy the evil than to lose trade? But are you taking out the maximum production from the rail mills you have, and have you the best adapted mills for making tin-plate bars? I question both, from what I have seen in this country and the States.

Do you keep your rail mill full of steel from six in the morning to six at night, as they do in the United States, where this is the rule and not the exception? If not, then that is one reason why you cannot get the same production and manufacture as cheaply. Do you keep two bars in the roughing and two bars in the finishing rolls at the same time? If not, then you differ from the American practice,—this, of course, on three-high mills,—and this is another reason why your output is not so great. But are your reversing mills adapted so that two bars can be handled in the same pair of rolls at the same time? Perhaps not, but such is the difference in conditions. It is my opinion that you try to roll too many

different kinds of shapes and sizes on the one mill, making your reversing mill a "Jack-of-all trades and master of none."

For a jobbing merchant mill, in my opinion, no mill is more suitable than a reversing mill, and when the Lindsay coil clutch gains the full confidence of the steel manufacturer, a reversing mill for rolling large sizes of merchant bars will become more popular than ever. However, in view of what is being done in the United States, we cannot admit that it is the best type of mill for rolling rails.

TIN-PLATE BAR MILLS

One of the "stock" arguments of the British iron and steel manufacturer, when his attention is drawn to the large production of the American rolling mills, is as follows:—"If we had such large demand for such special material as you have in the United States, we would not hesitate a moment to put in special mills and appliances to handle the material, and produce as much and as cheaply as you do."

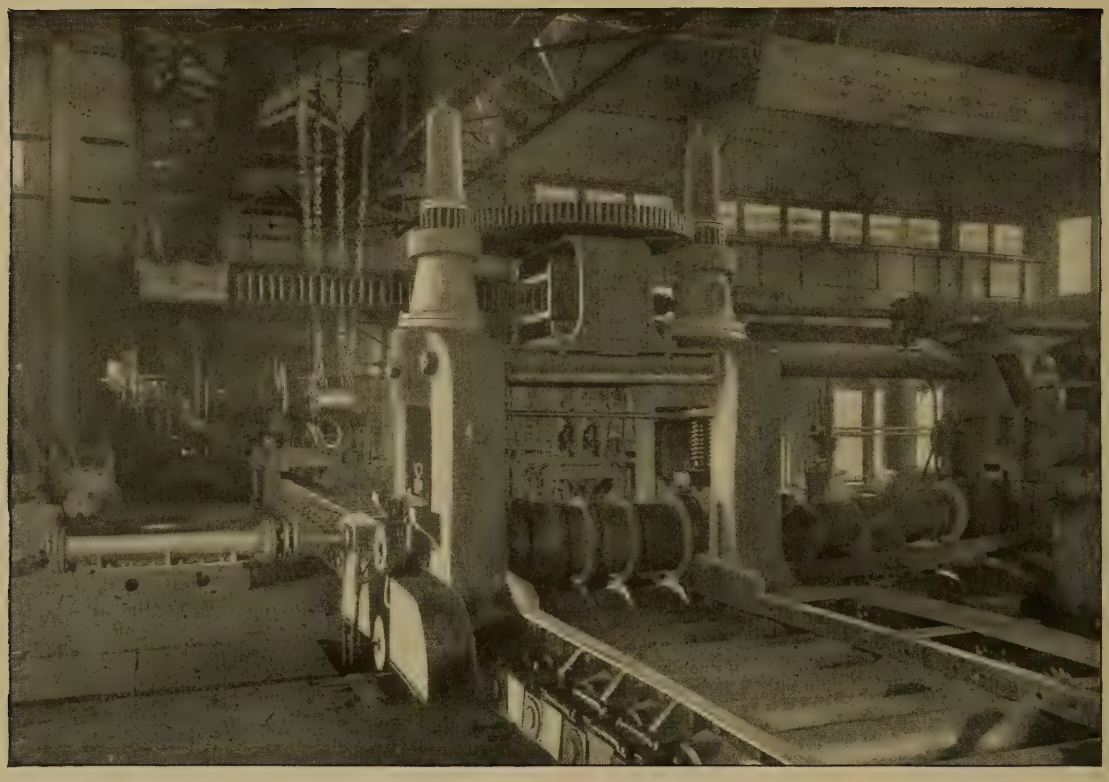
What about tin-plate bars? Prior to the year 1892 few, if any, tin plates were made in the United States, and yet they were the largest user of tin plate in the world. For years previous to that time they imported from Great Britain from 300,000 to 350,000 tons of tin plate per annum, and this was but 75 per cent. of what Great Britain made. Here we have a demand for about 440,000 tons of tin plate per annum, calling for approximately 550,000 tons of tin-plate bars every year. Isn't that a sufficient amount of special material, and enough to induce some one to put up special mills for making tin-plate bars? It seems not, for, if anything, the mills on which you make tin-plate bars to-day (after losing nearly all of that trade) are better than they were when you had almost a monopoly on the manufacture of tin plate for the world; so you must confess that due diligence was not exercised with a view to taking advantage of the favourable conditions at that time.

What did the Americans do, with the demand for tin-plate bars about 100,000 tons per year less? Some of the best, if not the best, machines in the United States for the rolling of steel are mills for making tin-plate bars, and to-day the Americans are pushing their tin-plate bars in thousand-ton lots right into your tin-plate districts.

Among the most noted tin-plate bar mills in the United States are the Duquesne plant of the Carnegie Steel Company, the National tin-plate bar mill at Youngstown, Ohio; that of the Bellaire Steel Company, at Bellaire, Ohio; and the mill at Vandergrift, lately owned by the Apollo Steel Sheet Company. Each of these mills is of a special type, and from the ingot to the finished bar,—even to the placing of the latter on the cars,—all of the work is done by machinery. The result is that steel-plate bars are sold for $1 per ton above (and in some cases less) the cheapest steel product in the country, namely, a 4-inch billet. It is true that these mills cost a great deal to build; but money is no object to the American manufacturer if he can see a fair return. Judged from my experience and observation, the British manufacturer seems rather conservative on this point. Here you are to-day with a large tin-plate trade, and no effort is being made to prevent foreign competitors from shipping tin-plate bars right into the country from a distance of 3500 miles.

STRUCTURAL STEEL MILLS

In regard to structural steel, I will touch but briefly on this subject, as I cannot see such a marked difference in the British and American methods, seeing that the Carnegie Steel Company roll all of their structural steel on the three-high system, while the Pencoyd Iron Works, at Pencoyd, Pa., roll their material partly three-high and partly two-high, and opinion is pretty evenly divided as to which is best and will make the larger tonnage. However, owing to cutting the ingots into two parts, and also the first and last end of the shaped bloom, which must be done on a three-high mill with a positive-running engine, and while the cost of labour may be less, the percentage of



THE BLOOMING MILL OF THE LORAIN STEEL CO., LORAIN, OHIO, WHICH HOLDS THE WORLD'S RECORD FOR 4-INCH BILLETS FOR 24 HOURS,—1260 GROSS TONS

finished product is greater on a two-high reversing mill,—which I understand is the practice in this country and on the Continent. In this case, it appears to me, the advantages are about equally divided.

PLATE MILLS

It may seem strange to hear an American say that he believes a two-high reversing mill for rolling plates to be better than a three-high mill with the small roll in the middle; but I must frankly confess that such is my opinion,—this, bear in mind, for plates 5-16-inch thick and above,—and were it not that a reversing engine takes more steam than a positive-running engine, I think there would be no question of the advantage in favour of a reversing mill. I base my opinion on the following:—

First:—There is no necessity of lifting tables, which are very hard to keep up.

Second:—If the three-high mill is better adapted to roll thin plates, the reversing mill is better adapted to roll thick plates. Placing a 5 or 10-ton slab on a lifting table necessitates the waste of a certain amount of energy in raising and lowering the said slab.

Third:—A reversing mill is better adapted for having extra sets of finishing rolls, which add to the life of the outfit and give a smoother surface to the plate.

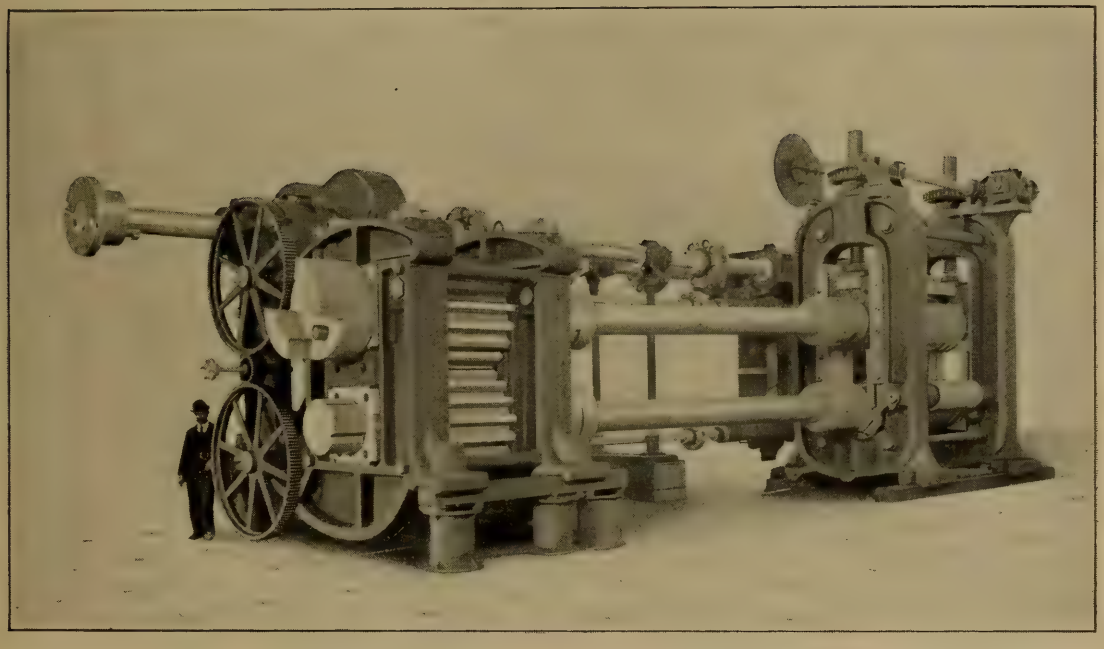
But, then, it may be said,—"Look at the enormous output of the American three-high plate mills, some of which have made over 10,000 tons of finished plates in a single month." To that I will reply,—Keep a two-high reversing mill as full of material as they do in the United States, and your product will be no less,—in fact, it ought to be greater. Go at any time during the day or night to see a three-high plate mill in operation at the Homestead Works of the Carnegie Steel Company, where, as regular as the tick of a clock, the slab is placed on the table which carries it to the rolls, one slab after the other, and often the slab has to be stopped to give time for the rolls to be raised to the proper place to suit its thickness. Do the same thing on

some of your modern plate mills in Great Britain, and mark the increase in the output!

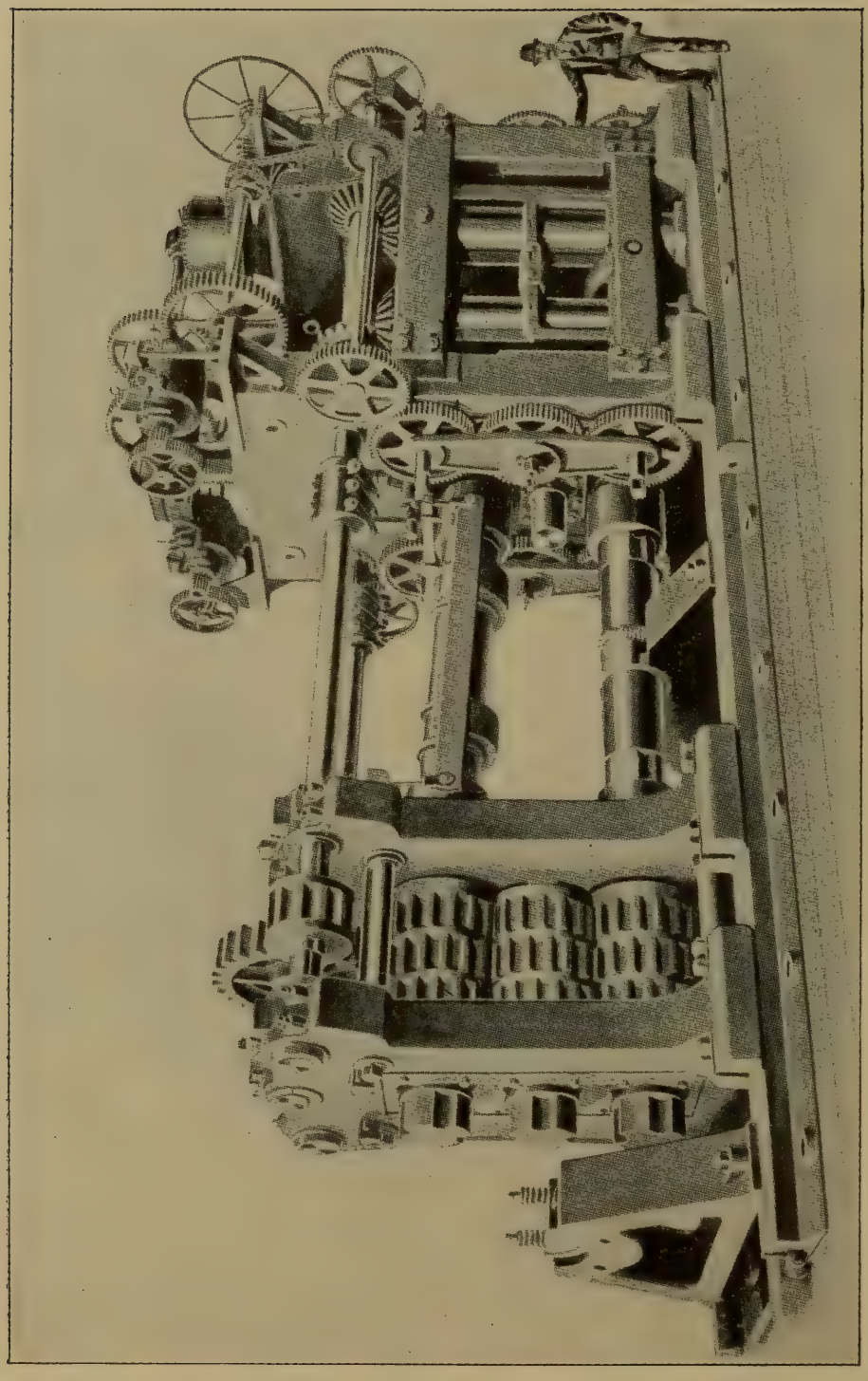
In rolling a plate ⅜ or ½ inch thick from a well-heated slab on a three-high mill, before it gets to the last pass or two, it is generally the custom to wait so as to finish the plate at the required heat, in order to get the necessary tensile strength and a smooth surface. You will observe exactly the same conditions on a first-class two-high reversing mill. If this be so, whence comes the advantage so far as output is concerned? On a three-high mill plates must be finished in such shape as to suit the market. Indeed, I believe that if some energetic American manufacturer would put in a two-high reversing mill with two stands of rolls, he would outstrip the present output of the three-high mill; for, while the plate is cooling to the required degree on the table of the finishing set of rolls, he will give the next slab two or three more passes in the first set, and to say that the British workman cannot be as active and energetic as the American workman, if it is his desire, is entirely wrong. I wish some of my American friends would visit some of your large steel works about a quarter to six, night or morning, or at the change of the turn, and see them hustle to get out all they can before the whistle blows; and again, who are the majority of the iron and steel workers of America today? Europeans, or direct descendants of Europeans, and the majority of them from Great Britain.

MERCHANT IRON MILLS

Before touching directly on your merchant bar practice, both iron and steel, I will give you my opinion as to the principal cause of your falling behind. It is simply because, up to the present time, you have had no competition, and my remarks following will prove this. Look back at your record for the past ten years, as regards the manufacture of iron and steel! True, there has been a slight and steady increase; in fact, you have not fallen behind your own achievements, but have failed only to keep up with the achievements of others. How many new iron and steel plants have been started in Great Britain since the year 1890? Few, if any, of importance. How many millions of money have you spent during that time on improvements? I may be wrong, but I will venture to make the assertion that during the past ten years all the British iron and steel



SLABBING MILL OF THE LUKENS IRON AND STEEL CO., COATESVILLE, PA. BUILT FROM DESIGNS OF JULIAN KENNEDY BY THE MORGAN ENGINEERING CO., ALLIANCE, OHIO, U. S. A.



THE FIRST THREE-HIGH UNIVERSAL PLATE MILL. BUILT FOR THE LUKENS IRON AND STEEL CO., OF COATESVILLE, PA., BY THE A. GARRISON FOUNDRY CO., PITTSBURGH. ONE OF THE BEST AMERICAN TYPES

manufacturers together did not spend as much money on improvements as the Carnegie Steel Company, in the United States, did in two years.

And why not? Has your right hand lost its cunning? Are your ingenuity and energy exhausted? You, who were at one time the greatest manufacturers of iron and steel in the world? I cannot believe it. It has been simply because you did not have to,—could do well enough without. Who gave to the world the Bessemer, the Gilchrist, and the Siemens processes? Great Britain. Who taught us how to make bar iron, wire rods, hoops, etc.? The British. Who gave us the continuous mill? Bedson, an Englishman. Who gave us what is known as the Garrett system of making wire rods? Great Britain and Belgium. Who gave us the best type of heating furnace for heating steel billets, which is now almost universally used in the United States, and is almost a curiosity in Great Britain? Allen, an Englishman. Who gave us the idea of a successful reversing mill? Ramsbottom, an Englishman.

I might go on indefinitely. Yet, having given us all this, we Americans have improved on them to such an extent that they can scarcely be recognised, and are to-day using them as a means to compete with you in the markets of the world. In the meantime, judging from some of your antiquated mills and methods, one would be led to believe that about forty years ago a Joshua once more commanded the Sun of Progress to stand still, and it has stood still ever since. And yet, when it was suggested to the management of some of your plants that by the introduction of some American methods a great saving in money could be made, the reply has been:—"Why should we? We made over 30 per cent. on our capital invested last year, and are satisfied with that."

Yet at that same time they were rolling by hand ¾-inch round bars in about 16-foot lengths, making about ten tons per turn, had one engine, which appeared to have been designed by Watt himself, driving four or five mills, all as old as the hills, eight or ten shears, and I don't know what besides. Can anyone admit there is competition in a country where such conditions exist? To be able to pay dividends in this enlightened age under such conditions is a libel on progress, science, invention, and ingenuity, and an imposition and a grievous and an unnecessary tax on the consumer.

I may say here that all of your iron merchant mills are not like that, but still this is not the only mill of this type in Great Britain. While you have some first-class mills for making iron, the main fact which I wish to convey at the present time is, that having rolling mills of this type paying dividends means that you have had little or no competition.

One of the best guide mills in the States for rolling iron is what is called the Williams mill, located at Youngstown, Ohio. This mill consists of a 16-inch roughing train and a five-stand 10-inch train, and they roll on this a box-pile, 5 inches wide and 6 inches high, containing over 60 per cent. scrap and less than 40 per cent. top, bottom, and sides. This is rolled into ¾-inch rounds in 100-foot lengths, and they make from 40 to 50 tons per turn. As I understand it, you have very few mills of this type in Great Britain; in fact, even in the United States this Belgian mill is not so popular as one might expect on account of its merit of being able to take a large pile and roll it on a slow-speed train when the pile is short and "dumpy," and when the bar is long, finish it on a train having a faster speed. These are the main features of the Belgian train.

MERCHANT STEEL MILLS

As far as I can see, you have not, up to the present time, taken steps in Great Britain in the direction of building mills specially adapted for rolling merchant steel. In the United States, during the past two years, great attention has been paid to this. First of all, it was found that the Allen type of furnace could be used for heating steel billets, whereas it was entirely unsuited for the purpose of

A MERCHANT MILL AT THE MILWAUKEE WORKS OF THE ILLINOIS STEEL COMPANY

heating an iron pile. The adoption of this type of furnace has reduced the cost of heating over 75 per cent. in labour alone, and it has been proved that in economy in fuel it is equal to the Siemens heating furnace. One of these furnaces can heat 135 tons of 4-inch billets in a single turn, and if the Laughlan patented arrangement for dropping the billets out of the furnace on to the conveyor is adopted in connection with it, only one heater, two helpers, and a man to push the billets into the furnace are required to operate two furnaces, which have averaged over 200 tons per turn for a whole month, the total cost per ton for labour being about 12 cents, or about 6d. in British money. As this is the maximum output on rod mills, it is but fair to state that when using the furnace for merchant mill purposes, where the output is less, this cost may be increased to 18 cents, or 9d. per ton. Without the Laughlan "dropping-out" arrangement this cost is about 25 per cent. more.

When we realise that this type of furnace is of British origin, and that any you may have in this country are looked upon as a curiosity, this is something to be greatly wondered at. This is one of the main agents in connection with the cheap production of wire rods and merchant steel.

Next, we have continuous trains to do away with the hard roughing-down. A 4-inch billet is rolled into, say, a ¾-inch round with only four men around the entire mill, doing all the work necessary to deliver the product on to the hot-bed. This includes one man to look after the continuous train. Merchant mills of this type, starting with a 4-inch billet, have produced as high as 445 gross tons of 1⅛-inch finished square bars in twenty-four hours, and have produced over 8000 tons in a single month. The sizes rolled on these mills are from 3 to 1-inch wide flats, any thickness, and from 1¾-inch to ½-inch rounds and squares, and, of course, are best adapted for the middle range of sizes.

On another type of mill for making merchant steel they start with a billet 30 feet long on all occasions, and vary the size of this to suit the size of the finished bar. This billet ranges from 1½ to 3 inches square, and in some cases the bars are finished about 300 feet long. Too much credit cannot be bestowed upon the Morgan Construction Company, of Worcester, Mass., on account of the fine point of perfection to which these mills have been brought. Their hot-bed arrangement is a work of marvellous ingenuity; 165 tons of 2½″ × ½″ is the best record I know of, but the mill has a still greater capacity. As to the merits and demerits of starting with a billet, say, under 4 inches square, I will say that whereas, outside of the fact that the capacity of the mill is controlled by the capacity of the furnace, as only one can be used, a 4-inch billet is sold in the open market in the United States for $1 per ton less than the smaller size billet, and the total tonnage labour to roll a 4-inch billet into a finished bar is less than $1, and as it does not take more fuel to heat this billet than is required to heat a smaller one, it seems to me that merchant steel rolled from a 4-inch billet is delivered on the hot-bed,—so far as tonnage labour is concerned,—at the same cost as the 1½-inch or smaller billet is delivered at the heating furnace.

On mills of this type a merchant bar can be finished and placed on cars for less than 14s. per ton above the cost of the billet. This includes loss, fuel for power and heating, and the cost of everything required to produce it; and when we come to the time when pig iron will again be sold for $9 per ton in the United States (which is equal to 37s. 6d.) and 4-inch billets for $14 (equal to about 58s.); add to this 14s. per ton for cost of conversion to merchant bars, we have 72s. per ton as the net cost. Then not only Great Britain, but also Continental Europe, will have what may be called competition.

As you have, so far, made no effort in Great Britain in the direction of putting in mills specially adapted to roll steel, I have nothing from which to draw a comparison except your present mills for rolling iron bars, on which you

roll steel also; but I will say here that it is impossible to get up a mill having the same advantages as the American mill I have described to roll both iron and steel.

HOOP MILLS

If I were to be asked what I consider the finest rolling mill machinery in the world, I would, without the least hesitation, say the continuous hoop mill at Youngstown, Ohio, designed and built by the Morgan Construction Company, of Worcester, Mass. On this mill results are obtained which have been thought impossible, and for nicety of adjustment and preciseness of relative speeds it is, in my opinion, the finest display of ingenuity in this line. This mill also has derived its main wonderful features, such as flying shears and coiling machine, from a Welsh engineer, viz., Mr. Edwards, of the Morgan Company. Fancy a 1½-inch billet, 30 feet long, and weighing 225 pounds, entering the first set of a continuous train and coming out of the last set ⅞-inch wide, of No. 20 gauge. After the hoop comes from the rolls, it is laid by a folding process on a slow-moving table, and the only one to touch the hoop with a pair of tongs is a boy, who picks up the first end and enters it into the reel, which coils the hoop up as neatly as a ribbon. The hoop is afterwards cut automatically into the required lengths for cotton ties.

The output of this mill is about 45 gross tons of ⅞″ by No. 20 gauge hoops, single turn. It is impossible for tongue or pen to describe this remarkable rolling mill machine. However, mainly owing to the impossibility of obtaining a uniform size throughout the entire hoop when finished, this mill has not met with the favour one would expect. For cotton ties or hoops which do not have to be of an exact gauge throughout it may be entirely satisfactory. Be this as it may, the fact is, the American Steel Hoop Company, or their predecessors, have built two hoop mills since this continuous hoop mill was built, and neither of them are of the continuous type throughout.

The most popular types of hoop mills are those having a continuous roughing train and looping finishing train of four sets of rolls, on which it is a common thing to make 45 tons in a single turn of 1¾-inch and 1½-inch by No. 18 or No. 19 gauge, or about 30 tons per turn of ⅞-inch by No. 20 gauge cotton ties. As to how much better these results are than those obtained in Great Britain, I will leave you to judge. From what I understand and have seen, you still have the old-style hoop mills of ten or fifteen years ago, and where your practice is most lacking is in the means to take care of the hoop as it comes from the last set of rolls. It is no trick, on a first-class hoop mill in the United States, to roll 1½-inch by No. 19 gauge in 200-foot lengths, and the piece will run out the entire length without being touched. Then, again, you roll iron and steel hoops on the same mill, which prevents the adoption of certain improvements, in particular in connection with the heating of the billets.

MILLS FOR ROLLING STRIPS FOR TUBES OR SKELP

In regard to strips, the finest mill we have in the United States for this purpose is a three-high universal mill built by the Garrison Foundry Company, of Pittsburgh, Pa., for the Lukens Iron and Steel Company, of Coatesville, Pa., on which mill they roll from 10 to 36-inch widths. They have but the one set of rolls three-high. I understand this mill is giving very good results, but the manufacture of this class of material, strange to say, has not been developed to any extent even in the United States. One reason for this is that it is only lately that the consumer has become reconciled to the use of steel pipe, the material for which alone will permit of any extensive and marked improvement in the method of manufacture. However, with what we have, our practice is far ahead of yours in Great Britain. On an ordinary 10-inch train over 60 tons of 4¼″ × 10″ strips have been produced in a single turn, and between 60 and 70 tons of from 6

to 10-inch strips per turn is a common thing on a 16-inch mill. This refers to steel strips.

I understand that in Great Britain you pay double the price for rolling strips that you do for bar iron, whereas in the United States we pay less than for rolling bar iron. Special rates are allowed the manufacturer by the Amalgamated Association to pay men rolling strips. This is, no doubt, owing to the fact that at one time nothing but cut nails were used in this country, of which over 6,000,000 kegs were made in a year, calling for over 300,000 tons of 12 to 14-inch strips. This made the rolling of strips so familiar and common, and competition became so keen between the cut and the wire nail, that reduction after reduction took place, which was naturally felt by the strip and skelp makers; and most of those nail plate mills, as they were called, are rolling strips to-day.

As the methods of rolling strips are about the same in both countries, I will close the subject by making the prediction that within the next five years more improvements will be made in the direction of improving the present method of making strips than in connection with any other process in the steel business, as the demand for strips is growing every day, and a production from 250 to 300 tons of strips per turn, varying from 10 to 22 inches in width, will be a common occurrence.

WIRE-ROD MILLS

I touch upon the subject of wire-rod mill practice last of all, because the striking developments and results by the American rod mills speak for themselves. There are two well-defined types of wire-rod mill in use in the United States, viz., the straight continuous and the improved Belgian types, the latter commonly called the "Garrett" mill. Were it not for the mills of the continuous type in operation at the works of the Washburn & Moen Company (now belonging to the American Steel and Wire Company) to such an extent as to become quite a formidable rival to the looping type, the continuous mill would cut but very little figure. Indeed, it is only justice to say that Mr. F. H. Daniels, of the American Steel and Wire Company, is the only one who ever designed and constructed a continuous wire-rod mill that could successfully roll more than one rod at the same time, and his last effort, in the wire-rod mill at Waukegan, Ill., is a masterpiece in that line. This mill starts with a 4-inch billet, and the output is nearly equal to that of the best looping mills,—about 350 tons to the double turn.

As to the rod mills of Great Britain, I understand that at Middlesbrough you have a straight, continuous mill which has been in operation for some time, but, for some reason or other, recently another mill was put in, of the Belgian type. Messrs. Richard Johnson & Nephew, of Manchester, have a rod mill partly of the continuous and partly of the looping systems. They, through Bedson, were the pioneers of the continuous mill, but have changed from a straight, continuous mill to part Belgian. The roughing train is continuous, and has vertical rolls in all cases, to reduce the ovals to a square. This is the finest mill of its kind in the world, and the manner in which these vertical rolls are driven shows remarkable engineering skill. But why have vertical rolls, which prevent you from rolling more than one bar at a time, when the "twist" guide will do the work just as well, and you could have all of your rolls horizontal? You have a four-high mill at Warrington which is much more complicated than a good Belgian mill. On this mill the bar, when it is square in cross section, is carried by means of what we might term a split pipe from the top two-high set to the bottom two-high set, the latter being speeded up in proportion to the reduction. As this is accomplished by a curved guide on all Belgian trains, saves the same labour and has no complication, and the output of some of the Belgian mills in Germany exceed this mill, this again seems a case of "much ado about nothing."

Then you have some of the very oldest types of rod mills in Europe, and to

show how far you are behind in output, at least, I will make the assertion that the four best rod mills in Great Britain, during the month of January, 1901, did not produce as many rods as one of the wire-rod mills in the United States, which during that month produced 10,230 gross tons of No. 5 rods,—indeed, I might make it five of your best mills and be safe. Here we have five different concerns,—five mills, five crews of men, five rollers (skilled men), five heaters (skilled men), paying the rollers, say, 25s. per day each, or £6.5.0, and the heaters 15s. per day each, or 75s., making a total of £10.0.0. for each turn's work, instead of one roller £2.10 and one heater 25s., or £3.15.0, or over 75 per cent. less, not to speak of the balance of the men; and I wish it to be understood that, in my opinion, the best men around the rod mills I ever saw are those who work on your present mills in England; so it is not the fault of the men.

The question might be asked, "If each of these five rod-mill owners had a rod mill of that capacity, what would they do with such a production of rods?" This I do not know, but if the present method of making rods is persisted in, the time will soon come when you will not make any rods, as there is already quite a surplus of rods in the United States, and when your steel makers find some means of giving you a cheaper 2-inch billet, to meet which price the American steel makers may not find it to their advantage, then they will deliver wire rods to Great Britain at a figure less than you are now paying for 2-inch billets. Is there no remedy, and will Great Britain give up the wire business,—she, who was the mother of that business, and has taught the world how to make wire?

Supposing the five largest users of wire rods in Great Britain were to combine and erect a large, first-class rod mill, but keep their business just as it is, and each party take stock in the new establishment in proportion to the amount of rods they would use. They could treat this new enterprise as an entirely new organisation from their present wire-drawing plants, and locate the new plant not far from a shipping port on either the East or West Coast. Then let us see how they would stand with a view to securing their raw material in the shape of billets! So far as their supply from Great Britain is concerned, conditions would be the same as to-day, but they could not only get their billets from the Pittsburgh district, as they are doing at the present time, but could also draw their supply from the Tennessee Coal, Iron, and Railroad Company, of Birmingham, Ala., who are located but a short distance from the seaboard; from the Maryland Steel Company, of Sparrows Point, Maryland; and from the Dominion Iron and Steel Company, whose plant is located at Sydney, N. S., or 1000 miles nearer Liverpool than is New York. No better source for a supply of billets could be had. When keen competition comes, the Dominion Iron and Steel Company, who can make the cheapest pig iron in the world, will always be able to make steel billets at a low cost. This same scheme can be applied to all who now make rivets, bolts, etc., or those who make tubes or pipe, getting soft steel billets to make their strips. In fact, if your raw material, such as ore and coal, is becoming scarce, and you can find a better market for your coal, selling it for steam purposes, then to manufacturers of pig iron or steel who, during time of competition, must have cheap coal, I can see no better scheme. For why import ore, which has over 50 per cent. of foreign matter, when you can import billets on which there is but from 5 to 6 per cent. loss from the billet to the wire rod, merchant or steel strip?

This same rule can be applied to those who use strips for tubes, and not only that, if the British iron and steel makers do not follow the footsteps of their American cousins, and combine, and then manufacture only their respective materials at the most advantageous points for shipment, and use the most economical method in manufacturing, the manufacture of iron and steel in time will become a lost art in Great Britain

Current Topics

In connection with generating and distributing electric energy it seems to be pretty well settled that the alternating machine is the form of electric generator which will be used in the future central station. When, however, we reach the consumption circuits, we find a divergence of practice, for the alternating current and the direct current both are adapted for this service. As pointed out recently by Mr. Charles F. Scott, chief electrician of the Westinghouse Company, in a lecture before the Franklin Institute, each has its own particular characteristics and types of apparatus; each has its particular points of merit; and each has points in which it is not so good as the other. The alternating current, however, possesses certain fundamental advantages, such as reduced cost for transforming apparatus, both in original investment and in attendance; reduced cost of conductors, as the distributing system is supplied from numerous widely distributed transformers instead of being supplied from sub stations; increased efficiency; and an ideally simple motor. The item of conductors for the distributing circuits becomes of very great importance where the conductors must be placed underground, and the cost of the copper alone may be small compared with the cost of the ducts or conduits in which the conductors are placed. Such items as these differ so widely in different cases that no general statement as to relative values can be made; each case requires special consideration.

A peculiar difficulty confronts the engineer at the present time which makes the problem of selection a double one. It is necessary, on the one hand, to utilise as far as possible the apparatus which now exists. This sometimes means the co-operation in one general system of many stations which were once entirely independent, each with its own particular class of apparatus and distributing circuits. This in itself is no easy task, but it is not sufficient to simply attain present results. There should be a plan which will lead to the ultimate system which will be the best. If apparatus is employed which is less efficient, more complicated, and less reliable than other apparatus, it is usually simply a question of time when the change must be made from one to the other. It is obvious that the system and the apparatus which are most simple and reliable in their operation are those which will probably be adopted ultimately.

The alternating system, therefore, has naturally the first claim to consideration, and upon the broad principles of simplicity it is the one which has the first place. The burden of proof lies with the direct current to show adequate compensation for the cost and complication which its introduction involves.

HAND GRENADES for putting out fires, which were common enough fifteen or twenty years ago, consisting of glass vessels filled with solutions of various kinds supposed to have special fire extinguishing qualities, date back to a much earlier time than is commonly supposed. Probably the earliest form consisted of a wooden vessel or barrel containing a considerable quantity of water, and having in its centre a small iron or tin case full of gunpowder. From this case a tube was continued through the side or head of the barrel, and was filled with a composition that readily ignited. When a room was on fire one of these machines was thrown into it, and, the powder exploding, dispersed the water in the outer receptacle in every direction. In 1723 Godfrey, an English chemist, copied this device and impregnated the water with an "anti-phlogistic" substance. He named his machines "water bombs," and the fire grenades of recent years seem to have been patterned very closely after them. In the year 1734 the Swedish Government offered a premium of 20,000 crowns for the best invention for stopping the progress of fires, upon which a German chemist introduced an apparatus of similar character. None of those early inventions, however, seem to have had longer careers than their short-lived successors of the present century.

IN forecasting the locomotive of the future before the New England Railway Club a short time ago, Mr. S. M. Vauclain, of the Baldwin Locomotive Works, expressed it as his opinion that coming improvements will embrace the further development of those feature invented during the past century, compounding of all locomotives upon some system now in use, and the introduction of the water-tube boiler, especially for high-speeds. Doubling or even trebling the power of locomotives for freight traffic would not seem improbable. As to the extent to which compound locomotives are now used, in the United States at least, Mr. Vauclain stated that four or five years ago the percentage of compound locomotives built by his company, based on the entire output of the works, was about 22 per cent. at that particular time. It struck as high as 27 per cent. twice, but it fell down to about 22 per cent. Last year the percentage was about 35 per cent. of the total engines built, but this basis for estimating the percentage is erroneous, for the reason that switching engines, mining engines, electric locomotives, compressed air locomotives, and various other specialties which they build must first be eliminated. After having eliminated all of those there are left road engines, and from these road engines must be eliminated the foreign locomotives which the works build. The percentage of compound locomotives is then nearly 70 per cent. This is the fairest basis for one to form an idea as to the extent which compound locomotives are being introduced on American railways at the present time.

AT the Baldwin Works it has been found also that the percentage of compound locomotives built for passenger service is about the same as the percentage of compounds built for freight service. The company build more freight engines than passenger engines, and consequently more freight compounds than passenger compounds; but the percentages are the same. Some of the railways have their passenger engines equipped with compound cylinders, but not their freight engines; while, on the other hand, other lines have all their freight engines built compound, but none of their passenger loco-

motives. It seems only a question of time until these railways will consider it just as profitable to operate the other arm of their service with compound locomotives as the arm that is now equipped with them.

One of the developments of the coming century, worthy of at least passing thought, is the extent to which pneumatic tube principle will be employed to expedite transportation which is now entirely dependent on steam locomotives. Mr. Vauclain, in the course of the remarks alluded to in the preceding paragraphs, directed attention, for example, to the long lines of loaded coal cars on their way from the mines to the seaboard, and back again, empty, to the mines. If the weight of a car is 25 per cent. of the gross load, there is in this instance more than 50 per cent. loss or non-paying freight, the empty train requiring about as much power to haul it up into the interior as was expended in taking it to the shipping port. It does not seem altogether unreasonable, therefore, to think that just as the miles of tank cars loaded with oil, which were seen in former years, have disappeared, and that commodity is now sent hundreds of miles through pipe lines, so may coal, grain, and ore be sent speeding through tubes to central depots for local distribution. In the matter of coal transportation, in fact, just such pipe line conveyance was tried experimentally something like ten or twelve years ago by the late W. C. Andrews, of New York, the coal for that purpose being ground into powder, mixed with water in sufficiently large proportion, and carried through the pipes in semi-liquid form. At the delivery end of the pipe line there were to be settling chambers for the mixture, enabling the water to be drained off and the coal paste, if we may so term it, to be pressed into cakes and dried for consumption. The project, however, did not extend beyond a brief experimental career. In woolen mills, on the other hand, it is a common thing to blow wool from one building to another through pipes by means of fans, and in potteries, too, clay paste is frequently carried from one point to another through pipes. There is, thus, a fairly good beginning for pipe-line engineering with solids.

In the piston bellows used in iron smelting by the natives of Madagascar we have an interesting example of the duplex pump in crude form. The outfit comprises simply the hollow trunks of two trees tied together, with suckers inside, bound with a species of palm leaf fibre as packing. The native who

PISTON BELLOWS OF MADAGASCAR

uses the machine alternately sinks one of the suckers while he raises the other. The little sketch on this page, illustrating the device, has been reproduced from Ellis's "History of Madagascar," published sixty odd years ago. The furnace is there described as a mere hole dug in the ground, lined with rude stonework, and plastered with clay. It was filled with alternate layers of charcoal and ore, and was covered with a conical roof of clay, a small opening being left at the apex. The bellows cylinders stood about 5 feet above the ground in which they were firmly imbedded. The lower ends were closed airtight, and a short bamboo tube conveyed the wind from each to the fire. As no mention is made of valves nor of openings through which air entered the cylinders, it is probable that the pistons were perforated for that purpose and the perforations covered by a species of

flap valve opening downwards, a device with which the natives apparently were acquainted. The bellows were of various sizes, generally from 4 to 6 inches in diameter. Sometimes only one was used, and it was then made larger, the attendant standing and working it with both hands. The cylinders also were not always perpendicular, but were sometimes inclined. The blacksmiths of Java used the same kind.

JUST as cable haulage for cars on steep inclines has in some places, on Swiss mountain railways, for example, been abandoned for the rack-rail principle, so it has been more recently proposed to do away with ropes in mine haulage, especially very deep mine haulage, in which the length and weight of the ropes contribute much to the difficulties of operation. A double rack is to be fitted to the side of the shaft, with cogged wheels of a small carriage gripping it and engaging with it. These wheels are to be driven by an electric motor with power transmitted by wire from the surface. Worm driving, further, is proposed for the cog-wheels, so that there would be no danger of running down should an accident happen to the motor. With this arrangement, or something like it, there would be no greater weight to lift at any time than the weight of the carriage and its load, however deep the mine.

THE use of special machinery is a noteworthy feature of modern industrial development. It is, says *The Iron Age*, the result of persistent study to reduce costs, to increase output, to make more perfect goods or to manufacture newly invented articles satisfactorily and cheaply. It has been well said that an American mechanic not only invents wonderful labour-saving machines, but he also invents machinery to build the machines. This statement was never so widely applicable as it is to-day. Whether one visits implement factories, tool making shops, stove works, novelty factories or small shops making specialties, he is impressed with the fact that the presiding mechanical genius of the establishment has evolved machines to greatly expedite the work at various stages or to accomplish some difficult feat in shaping metal. It is one of the peculiarities of American mechanics that in the evolution of an idea a device of totally new form may be found an essential part. When perfected, perhaps no standard machine or process will produce it to the satisfaction of the inventor. It may sometimes happen that an invention cannot be utilised because it requires a part or parts too difficult or expensive to make for the purpose. Ordinarily, however, the inventor is not vanquished by such an obstacle, but proceeds further and originates a method by which his purpose is accomplished. Much is being done in this way in small shops, in which the use of special machines would hardly be expected. It can be said, however, that few metal working factories of any pretensions can be found in which the machine shop is not employed to some extent on special machines for their own use, and which are preferably built on the premises. The experimental department involves considerable expense, and much money may at times be sunk in it without an adequate return; but it is found necessary for the vitality of the enterprise. The manufacturers who do not experiment or who are not on the alert to find something better than they are using or producing are in danger of being left in the rear. This peculiarity of American mechanics is what has given American manufactured products such an ascendency in the world's markets. And this ascendency they will hold until some other race or nation develops a superior faculty for originating machinery. Foreigners who have, as they believe, Americanised their plants by equipping them with the most modern American machinery, have not, after all, secured the secret of American mechanical success That cannot be transferred, although it is no longer a secret. It is to

be seen in practically every workshop, and its sign is the special machine.

THE strong movement which has come about in favour of electric railways in Germany has made itself felt in Russia, although there is not at this moment such a pressing need of quicker means of communication between the provincial towns of the latter country. Still, under certain circumstances, Russia may develop such a need. During the summer of 1900, as told recently in *The Engineer*, of London, M. Romanoff constructed at Gatschina, twenty miles from St. Petersburg, a small electric railway on a system which he had invented, and the results were thoroughly satisfactory. M. Romanoff now desires to apply his system to a railway on a much larger scale, and he has drawn up a project for constructing an electric railway from St. Petersburg to Moscow. It has long been well known that the existing Nicolas Railway, connecting the old and new capitals of Russia, and 404 miles in length, is unable to cope with the traffic. The authorities entertain the idea of separating the passenger traffic from the goods traffic, and for this purpose it is said that two other tracks are to be laid down. However, M. Romanoff has now come forward with a proposal to construct an electrical "hanging railway," which shall take the place of increasing the carrying capacity of the present line by the addition of two tracks. The cost of this suggested railway would amount to 98,000,000 roubles, and the yearly cost of its working would represent 12,819,000 roubles, of which sum 80 per cent. is absorbed by the cost of fuel. M. Romanoff computes that the cost of passenger traffic will come to about half a kopeck, or ¼ cent per verst of two thirds of a mile. The rate of speed to be attained on this "hanging railway" is estimated to be 120 kilometers an hour, with a limit of 200 kilometers, as occasion shall demand. This is the normal rate of speed of the electric railways of the future, according to the views held by experts. The project thus put forward by M. Romanoff has aroused a great deal of interest in St. Petersburg, and it would undoubtedly increase its claims upon the attention of the public if it could be shown that it would be constructed with more regard for the interests of the region through which it will pass than was the case when the present railway between St. Petersburg and Moscow was built. It ought not to be a difficult matter for the projected railway to take in its route a few of the towns which the Nicolas Railway left cut off from communication by rail with the outer world.

EBEN ERSKINE OLCOTT

President of the American Institute of Mining Engineers

A BIOGRAPHICAL SKETCH

AT its last annual meeting, held in February, the American Institute of Mining Engineers elected Mr. Eben Erskine Olcott as its president. Mr. Olcott is a New Yorker by birth and education, and received his early school education at one of the famous New York grammar schools, from which eventually he went to the College of the City of New York.

Later he took up his scientific studies at the School of Mines, Columbia College, and graduated from this institution with honour in 1874. Almost immediately he received an appointment as chemist in charge of the Hunt &

Douglas process on copper properties in North Carolina, and after remaining there one year he was appointed assistant superintendent of the Pennsylvania Lead Works, at Pittsburgh, Pa., under the well-known lead metallurgist, E. F. Eurich. This was in the early days of lead smelting in this country, and it was here that some of the very rebellious silver-lead ores from Colorado were first successfully treated. His next position was as assistant superintendent and later superintendent of gold mines in Venezuela, near the famous Callao mine. On his decision to return to the United States, after three years of diligent work, he was offered many tempting positions from the various companies operating in the Venezuelian gold fields. He saw active practice in the mines of San Juan County, Colorado, and travelled extensively for New York capitalists through many parts of Colorado, Utah, Nevada, and California until 1880, when he accepted a position in Mexico where he spent several years.

In 1885 he opened an office in New York as consulting engineer, and has continued the practice of his profession from that city ever since, having been sent on many important missions to South America, Mexico, and the Western States. He was for some time identified with the development of gold fields of Dutch Guiana. In 1886-87 he was a member of the Cerro de Pasco Mining Commission, which made a special study, by diamond-drill explorations and in other ways, of the famous silver mines which have been extensively worked from the earliest times, and in which large bodies of copper ore are now being opened.

In 1891 he thoroughly examined the inaccessible and little known Sandia and Carabaya gold region at Peru, situated on the headwaters of the Amazon, on the east slope of the Andes. This country is so utterly destitute of roads that, for the most part, not even mules can be used, and transportation is effected almost wholly on the backs of men. Gold is found from an elevation of 17,000 feet on the Ananea Mountains, to the banks of the Huari-Huari River at an elevation of 3000 feet. In most places, however, the industrious aborigines, the Incas, have been ahead of the white man, and have exploited a great deal of the gold. Mr. Olcott also examined the Huantajaya silver mines back of Iquique, Chile, and has also seen parts of the mining territory of Ecuador and Colombia.

In 1895 peculiar circumstances made it desirable for him to undertake the management of the well-known Day Line steamers, plying between New York and Albany. The same industry which characterised his work in the mining field made him successful also in this new line of business. To maintain his connections with mining engineering he formed the firm of Olcott, Fearn & Peele, which, subsequently, by a new arrangement with Mr. Christopher Robert Corning, a distinguished graduate of Freiberg and Heidelberg, became Olcott, Corning & Peele.

Mr. Olcott is one of the managers of the Engineers' Club, and a member of the University Club and the Union League Club, of New York, the Down Town Association, and the American Society of Civil Engineers. Of the American Institute of Mining Engineers he became a member in its early days, twenty-seven years ago.

During the forthcoming extensive trip of the Institute to Mexico Mr. Olcott's acquaintance with the Mexican people and their language will stand the members in good stead.

PHOTO BY LA ROCHE, SEATTLE, WASH.

Yours truly,
Leo Dash

SEE PAGE 263

CASSIER'S MAGAZINE

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RAILWAY ENGINEERING IN CHINA

By T. Johnstone Bourne

SECTION HANDS

THE present article refers only to what is known as the Northern Railway, built, from the driving of the first spike, and earlier from the construction of the "Rocket of China," by Mr. C. W. Kinder, M. I. C. E., C. M. G., as engineer-in-chief and leading spirit. The earlier sections of this system were running and doing useful work as standard-gauge lines before any other existed in China, save only the light railway of from ten to fifteen miles, from Shanghai to Wu Sung, which, almost directly after its opening, was bought up by the Chinese and entirely demolished.

The several sections in which the Northern Railway was built may be traced on the map given on page 183, and had the following sequence and objects:—

1.—From the coal mines at Tang Shan to the nearest practicable point for a canal, Hsu Ko Chung, to get coal down to the sea.

2.—From Hsu Ko Chuang to Tang Ku, a river port inside the bar of the Pei River, with the same object.

3.—From Tang Ku to Tientsin, an obvious connection between the port and the great entrepôt of North China, a connection then, as now, ill made by the shallow and shifting waterway.

4.—From Tang Shan to Shan Hai Kuan,—the first step towards tapping the richness of Manchuria and providing transport and communication along a somewhat inaccessible region, halting temporarily at an important military station and on the frontier of Manchuria.

5.—From Tientsin to Peking, the capital city, with its large, concentrated population and its centre of officialdom.

6.—Extension from Shan Hai Kuan towards the capital of Manchuria and a rich agricultural and mining country, with a branch to Niu Chuang, the northermost treaty port.

7.—From Peking to Pao Ting Fu, the first section of an arterial trunk line from Peking southwards to Hankow, on the Yang Tze River, with a branch

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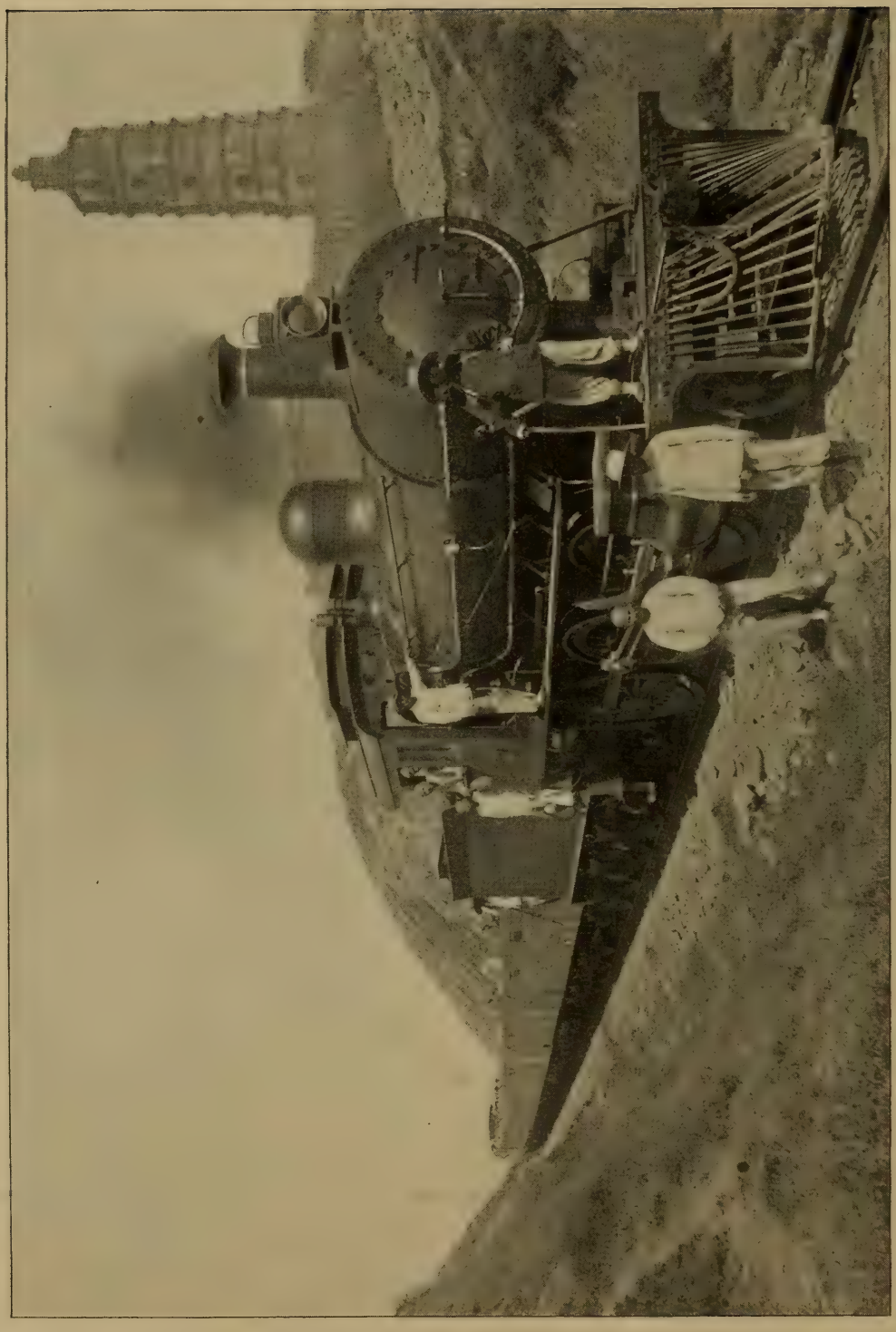


A CUTTING AT LIANG HSIANG HSIEN SHOWING A ROGERS LOCOMOTIVE HAULING A TRAIN OF COAL CARS

to native anthracite mines, stone quarries, etc.

The total length of these lines is about 600 miles, and by way of realising the amount of country covered it may be compared on the map of Great Britain to a railway from London, through Sheffield and Newcastle to Edinburgh, with a branch to Glasgow, and another line from London through Reading to Bristol, and on to Plymouth. Most of the line is single track, but that from Tientsin to Peking is a double-track road. That from the junction near

A SURFACEMEN'S GANG, WITH SECTION FOREMAN

Peking to Pao Ting Fu has earthwork and the masonry of bridges prepared for double track, but girders and rails for only one track at present. The rail on these sections is eighty-five pounds per yard, and flange rails of Sandberg's pattern are in use over the whole system, except for about sixty miles on the Peking-Pao Ting Fu line, on which rails rolled in Hanyang, on the Yang Tze, are laid. These also are flange rails spiked to the transverse sleepers, and having long, four-bolt angle fish-plate joints. Seeing that over the whole North American Continent practically no other rail is known than the Vignoles flange rail, that the fastest and heaviest trains in the world are there run over some of the sharpest curves, that the smoothness of running on the better, eastern, and dividend-earning roads is not surpassed anywhere, and that a flange-rail track is cheaper to lay and maintain than any other, it is difficult to see why the British Board of Trade and British railway officials refuse to give it a retrial.

The flange-rail with a base-plate has at least as great a resistance to side pressure or shock as any chair-rail, as four spikes may be driven, if necessary, through the base-plate at sharp curves or turnouts, all four coming into action in either direction; and as the flange sits right down on the base-plate, the vertical arm of the overturning moment is less than with a chair fastening. The bearing area on the sleeper is, or may be, equally great in both cases, and the base-plate has the great advantage of allowing some slight elastic transverse play of the rail on its upper surface without chafing the sleeper.

Whether from intrinsic necessity or more hard thinking the joint of a flange rail is theoretically and practically far superior to that of a chair-rail, firstly, because a flange-rail with an angle fish-plate is always provided with holes or notches in the horizontal leg of the angle to take spikes through it into the sleeper. These joint spikes set a limit

THE PAO TING FU RAILWAY STATION

to the creep of rails, to the total longitudinal creep, and to the local creep of the joints out of square. The chair-rail has no such device. Secondly, the strength of, and continuity over, the joint is infinitely better in the angle-fished flange-rails. The chair-rail joint has its joint sleepers originally far enough apart, because the fishplate comes in contact with the chairs and sets a limit to their contiguity; but it generally has them much further apart than this original limit, because the rail has crept in one direction leaving two cantilevers of unequal length with a joint between them. This joint is commonly kept together by a comparatively shallow bar, which does not rest on the contiguous chairs or sleepers, and cannot be said effectively to "bridge" the gap.

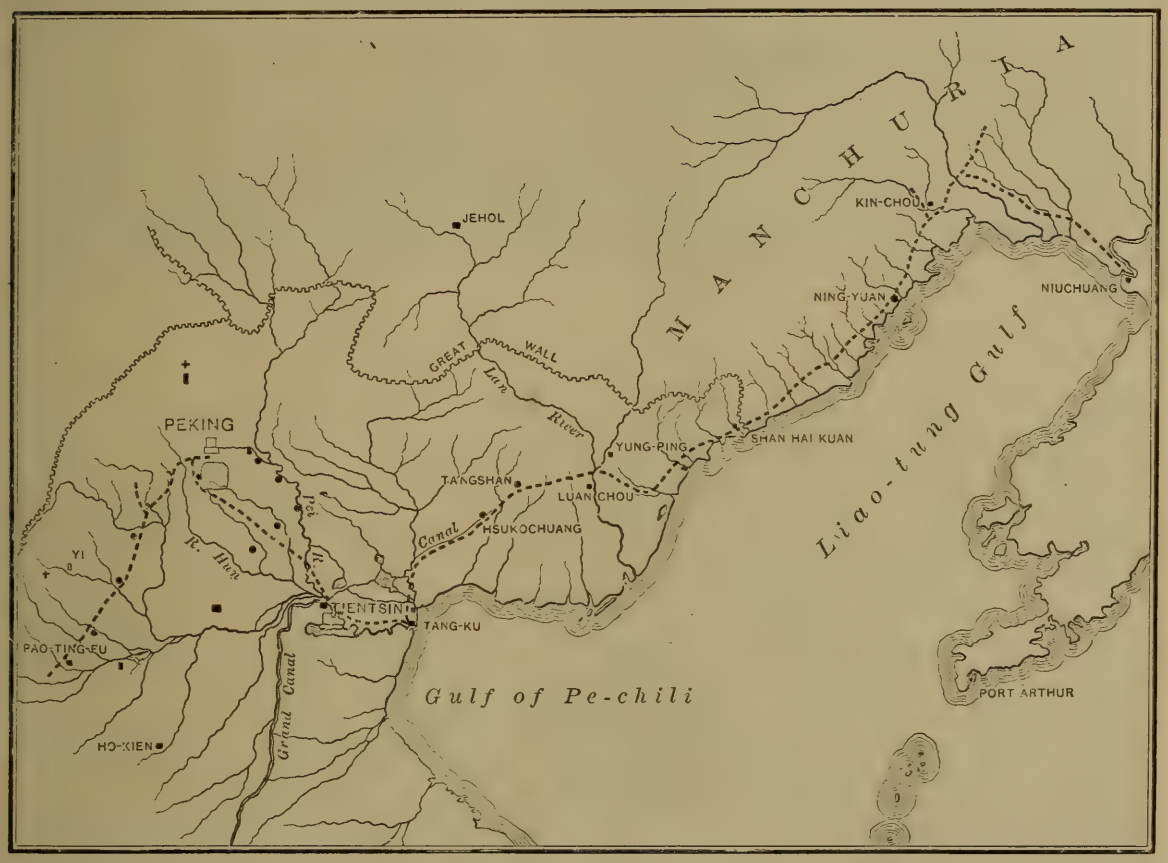
The angle fish-plate is permanently attached to the joint sleepers, on which it always bears, is longer and stiffer than the "plate," and both as a longitudinal splice in a bar and as a bridge to carry the load and diminish the deflection at the joint, is far ahead of its rival. It is a sound mechanical job. Attempts to mitigate the joint trouble have often taken the form of a "supported joint," *i. e.*, a joint chair coming on top of a sleeper directly under the joint. This has not found favour, and somewhat naturally so, as in such case the whole jar and shock comes on this one sleeper absolutely and without any elastic medium, and it is found impossible to keep this sleeper up to its work. Probably the best attempt so far at an efficient joint is the one in which a short length of rail is put outside the main rail and takes the outer part of the wheel tread while the joint is being crossed. This also is an application to the flange-rail.

THE CHINESE IDEA OF A RAILWAY RESTAURANT

Exceptionally liberal construction gauges are worked to on the imperial railways of North China,—16 feet clear headway from rail level, 12 feet 6 inches between centres of tracks on main line, 13 feet 6 inches in stations and yards, and 7 feet 10 inches side clearway, with passenger platforms 2 feet 3

inches above rail level. These standards have been approved and imperialised by the Board of Railways in Peking, and it is to be hoped that they will be maintained as minima for all future work throughout China. The upper view on page 184 of Liu Li Ho station yard on the Lu Han Railway shows the tracks at this junction with a mixed train and construction train in the station, while the lower railway was being worked by foreigners, and expressed to the native mind the foreign idea, may have given a logical enough aspect to the work of smashing and burning.

It will be noticed that raised platforms are adopted. These are a natural complement of mixed trains, as mixed trains are themselves an economic necessity in cases of very light traffic. When there



MAP SHOWING THE SEVERAL SECTIONS OF THE NORTHERN RAILWAY

view shows the water tank, engine shed, etc., at the same place.

At this station the first acts of violence by the Chinese boxers occurred. They burned down the ticket office and station buildings, and pulled up the rails in the yard. The fact that these rails were rolled in South China by Chinese, that the construction of the line was carried out by the desire of the Chinese Emperor and officials, and was made full and appreciative use of by the native merchants, shows with what mixed motives the movement was carried through. Perhaps the fact that, at the time, the is established in China a "Board of Trade" which insists on from twelve to twenty axles being a load for an engine, so as to keep passenger trains separate from goods trains, then a paying railway in many of the districts which would well support one will be impossible. Even in China passengers are not prepared to be confined to one train per day, on the one hand, and on the other hand, it is only by getting few engines and small working staffs to do the work, and loading these engines to somewhere near their capacity,—say, 80 to 100 axles,—that economy of working can be

THE LIU LI HO STATION YARD

ANOTHER VIEW, SHOWING WATER TANK AND ENGINE SHED

effected. The raised platforms, as already intimated, are due to the nature of the traffic, which is sensitive in its own peculiar way, and must, to some extent, be humoured. An upper-class Chinaman riding or driving to the station requires his ponies and carts at the end of the railway journey, and these must, therefore, be bundled on to the train while it waits. Small merchants travel with large bundles of merchandise, and these must all be quickly loaded up from a platform. A goods shed, special loading bank, and a yard full of empty cars at each small station will not help a railway in a thin country to pay dividends. Where it is possible to fill a passenger train and to run it as such, economi-

cally, however, it is done, as on the Tientsin-Peking line, where a distance of eighty miles, with several stops, is covered in two and one-half hours.

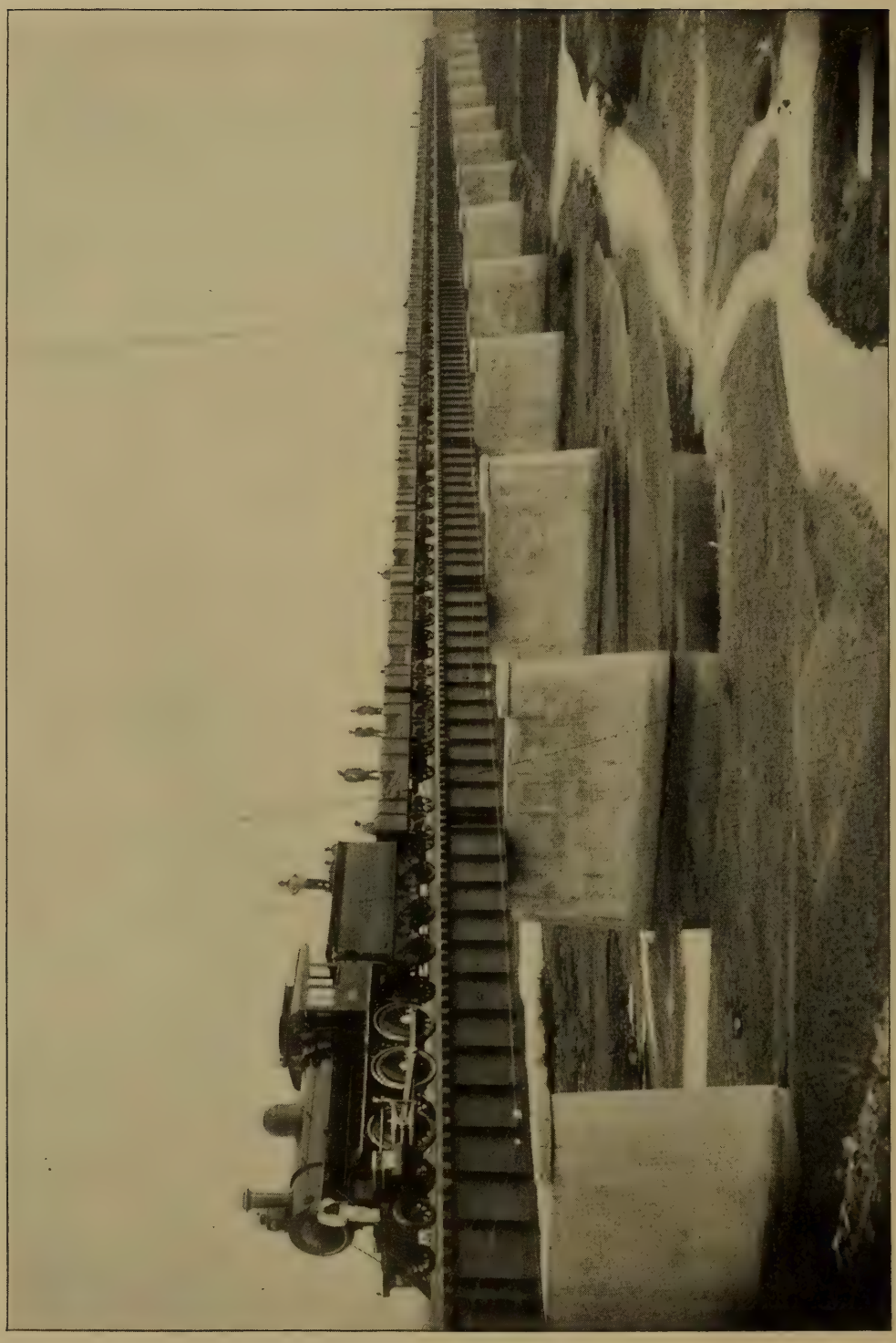
All bridge masonry is of ashlar or concrete. The latter is, of course, far cheaper in every case and fully as good, and, therefore, has been adopted for the last six or eight years. With the exception of one or two small arch bridges whose abutments were built of rubble in cement mortar, and one subway at a station, all structures on the Peking-Pao Ting Fu Railway were built of Portland cement concrete. The notion that concrete is a cheap and nasty substitute for masonry seems likely to be decently buried shortly, but has died very hard, if indeed it is quite dead. The contempt in which it has been held may probably be traced to its original form of "two barrowfuls of ballast and one of lime."

A concrete consisting of a definitely proportioned volume of mortar mixed with a volume of stone just suited to it, is a scientific and reliable product. Portland cement is now well understood and can be specified with all requisite minuteness. Its fineness, chemical composition, soundness, tenacity, adhesion, speed of setting all are clearly and simply measurable quantities, and can be reckoned on as surely as those of steel. The strength and other qualities of any combination of this cement with any volume and quality of sand are readily ascertainable. It remains only to select a sound stone which will break down into good cubes and spalls of varying size, and giving, therefore, the least proportion of voids. Out of this is made a rubble in cement structure which is none the less such because the rubble is small and the method of laying stone by stone with a trowel is abandoned, and a shover and plate or concrete mixer is used instead of imbedding each stone and each spall in the mortar required. We obtain something better, however, than the best rubble in cement, for the matrix is continuous, and forms a mesh having a definite tensile strength of its own which is cumulative with its adherence to the aggregate.

A material made and used with this conception is not on the same footing with the "one cement to six 'ballast'" (or 1 to x) of the old specifications and schedules. The "1 to 6" mixture may result in a few stones set in 1 to 5 mortar, or 5 parts of stone set in 1 to 1 mortar, both of which will result in bad concrete and waste of good cement, while some intermediate and unspecified ratio of cement, sand and stone may give the economic proportions.

Nor is there any need for cement concrete structures to emulate bad rough cast, colossal sponges, or stuccoed cottages. A proper composition, good mixing, a little care in "feeding" or light ramming, and a really well finished mould or shuttering will give a surface almost, if not wholly, free from air and leakage holes. If such as exist are pointed when the moulds are down, and if the surface is rubbed over with a board and sand while the concrete is fresh, an excellent and a wholly honest finish will result. If desired, any suggestion of the thing that is not may be given with false jointing, but probably

FOR STEALING SLEEPERS



BRIDGE OVER THE CHU MA HO

most engineers prefer a homogeneous finish to their monoliths.

The foundations of most bridges on the Peking-Pao Ting Fu Railway are on piles, the country traversed by the main line being, for the most part, an alluvial plain, rock having occurred at one point only where the line was in a cutting, as shown in the illustration on page 180. The northern country can provide little or no timber, and none suited for piles; but these are procurable from the country around Foochow, and "Foochow poles" are known all over China as building and scaffolding material. Pile-driving was performed both by hand and with steam winches and was carried on as fast as the available number of piling engines permitted. In one bridge oval walls of concrete were sunk for the foundations of a few piers, and in another the pneumatic system was adopted for the channel spans of a bridge over a river subject to great speed of current and having a dangerous shifting bed.

The principal bridges on the Peking-Pao Ting Fu main line of eighty miles are the following:—

Over Hun Ho, 15 spans 100 feet	=	1,500 feet
" Liu Li Ho, 12 spans 60 feet	=	720 "
" Chu Ma Ho, 15 spans 60 feet	=	900 "
" Pei Ho, 11 spans 60 feet and 18 spans 30 feet	=	1,200 "

In all, there are eighty separate bridges of 10-foot span or over, aggregating about 8000 feet in length of clear span, or an allowance of about 100 feet linear opening per mile of road. This being almost entirely provision for waterway, and the fact that such few bridges as it is considered necessary to allow for cart traffic are invariably also floodways for water in the rains, shows the great amount of water for which it is necessary to provide way across the line. The country for about nine months in the year is perfectly dry, and freedom from rain can be almost certainly counted on. In the winter there may be a few light falls of fine snow which is quickly blown and evaporated away or melted by the sun at noon, but even in winter the air is so dry in North China that a match, dropped on the ground, will set fire to the short grass. In July and August, however, the rains are due, and the year's rain falls. Then half the year's rainfall may occur in a few separate bursts such as are unknown in Great Britain. The rivers, of which many for nine months are dry, sandy tracts, are suddenly filled with flood water, which bursts down a waterway wholly unprepared for such volumes, floods the surrounding country, and makes practical and severe test of every bridge and culvert.

CONCRETE BLOCK PROTECTION FOR BRIDGE PIERS

The casual visitor, and even the European engineer going over China roads and railways, is puzzled to see bridges of considerable length and size apparently in the middle of ploughed fields, or perhaps spanning what looks like a harmless marsh. Nothing but a sight of the same or similar places during, or just after, a rainfall will convince him of their necessity. In the rains, however, these innocent-looking places, a casual glance at which scarcely reveals a depression in the ground, become the beds of torrents of vast areas of moving water which must either pass under the line or breach it. This is shown in the illustration on page 186 of the Chu Ma Ho bridge. This bridge

A 10-FOOT CONCRETE ARCH

is at one end of a valley about two miles wide, having three other smaller bridges in its length. The mere trickle of water through it is clear in the picture, the photograph having been taken in the autumn after a rather dry summer; yet this bridge in a heavy rain is running full to within a foot of the girders, and the valley is flooded to an average of 10 feet or more deep for its whole width. To show the nature of its bed and the speed of the current it may be mentioned that a 12-inch pile, 24 feet long, and driven 20 feet into the river bottom for a temporary bridge, was washed out and carried down stream in a minor flood. The extent of protection needed in some of the more torrential rivers is shown in the illustration on page 187, where concrete blocks weighing 1600 pounds are shown put round the piers of a bridge. Nevertheless, in one case one of these blocks was carried bodily by the current about 1000 feet down stream.

For minor bridges an allowance of one inch per hour run-off from the area drained is the least that can be considered safe, and in small culverts even this may be exceeded for short periods of time. With such a rapid rate of rainfall following on preliminary "small" rains which soak the surface soil, absorption has little influence after the first five minutes of rain, and practically all the fall may be considered to run off.

Pending a proper cadastral survey of the country the discharge from the catchment areas of the great rivers cannot be discussed. Nothing but prolonged special experience in the country and the judgment thereby accruing suffice to determine economical flood openings, probable depth of scour, velocity of current, and suitable foundations under present conditions of China's knowledge and records. These last are there kept somewhat as ours were a few hundred years ago. The height of a record flood, for example, is recalled to the dwellers in Chinese hamlets by the fact that it came up to their potato patch, or their doorsteps, or their windows, and vastly as such records always vary, patience will generally elicit corroboration and fairly reliable evidence.

All bridges have standard girders of standard spans. These were designed by Sir Benjamin Baker, K. C M. G., the consulting engineer for bridges on the imperial railways. During the last six years the greater number of these have been made in China in the bridge works belonging to the railway. It has not been found necessary to use special girders, nor is there a skew girder bridge anywhere on the system. In no case has it been found that the extra cost of such a structure can be economically compared with that involved in diverting a stream or roadway under a standard bridge put on the square.

Station accommodation involves living rooms and offices for a native station-master, ticket office clerks, telegraph clerk, and servants and station coolies for these. On the Peking-Pao Ting Fu road these offices were set back from the main track in the case of most third-class stations. At the prefectural city of Pao Ting Fu the station building was on the platform, as shown on page 182. These structures are built of native brick, which, though a poor structural material where weight and strength are desired, is quite good enough for ordinary building, and stands the weather well. Roofs are all of corrugated iron, which alone is tight under all conditions of weather, and which gives no trouble and expense in upkeep of repairs. The illustration on page 182 shows the local

MASONRY AND CONCRETE SUBWAY AT PAO TING FU

A SWITCHING ENGINE

form of railway restaurant at a wayside station. This is all that native taste and epicureanism desire, and fills the requirements perfectly.

The construction of bridge masonry was carried out after the rails had been laid to and past the bridges over diversions, and, where necessary, over temporary timber bridges. Permanent track was laid on the completed formation between structures and temporary track over the diversion roads. Through running of trains was thus established over the whole line before the masonry of the greater number of structures was commenced. Concrete ballast and rubble from a quarry on a branch line, as well as cement, sand, and plant, could then be cheaply moved in full train loads to the required sites, and an immense economy was effected over the system of carting supplies and finishing the bridges before putting down the rails. The total amount of ballast and rubble hauled was about 200,000 tons, and for every train load of this about 1000 cart journeys would have been needed, or 10,000 journeys of pack mules. Cartage was, therefore, confined to piles and pile-driving plant, and to the small amounts of ballast, sand, and cement needed to complete the culverts and a few of the smaller bridges for which diversions, even at the cheap rates for earthwork, would not have been justified.

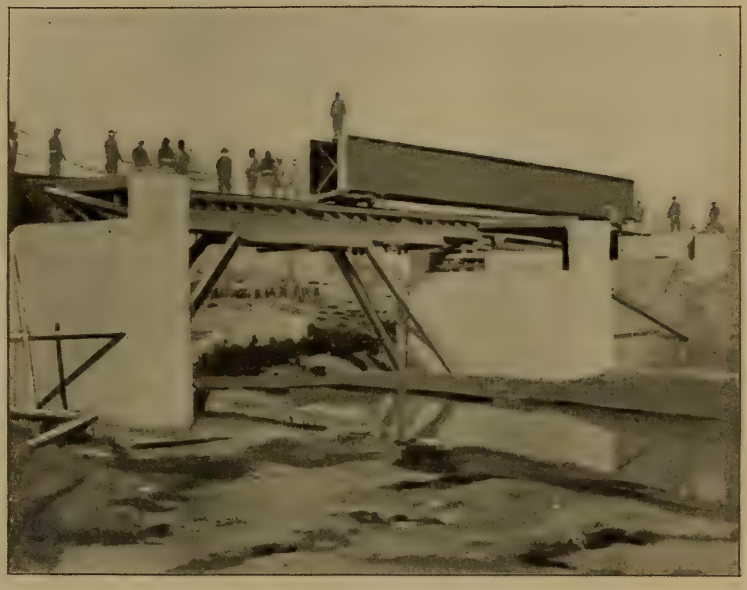
A temporary bridge over a creek, with the permanent bridge behind it ready for girders, is shown on page 192. The erection of a 60-foot girder is shown on page 191. In this case the two main girders were sent complete from the bridge yard to the site of erection, the riveting-up being done on firm ground on the formation behind the abutments. The completed span was then put on two ordinary material trolleys and launched across the already erected spans and a temporary bridge. The track over the temporary bridge was then taken out and the girder lowered on to its piers with jacks.

The execution of earthwork in China is a comparatively simple matter. As in all countries where land and labour are both cheap, banks are made from side cuts, and a large amount of the excavation from cuttings is spoiled on the top and at the two ends. Unsightly as all this may be, there is no escape from the methods which tend to maximum economy, and the equalising of earth-

work and use of tip cars for any considerable length of haul cannot pay under the conditions of labour prevailing in the East. Extensive earthworks of all kinds have been constantly in progress for thousands of years in China, and the Chinaman can do all this work without being taught. Centres and levels being given, there is an unfailing supply of men who can do the rest without any white help in the organisation of the undertaking. It is necessary to deal with only one responsible native for perhaps every fifty miles of road. A contract is made with him, and there remains only to measure up and issue certificates for completed work. The labour for this work is special and seasonal. It may commence as soon as the frost is out of the ground, but can continue only until the first harvest is ripe and the floods near at hand. Then the earthworker must return home, get in his harvest, watch his home through the floods, and, if he has luck and it is not under water, reap the second harvest, for he comes generally from the flood districts.

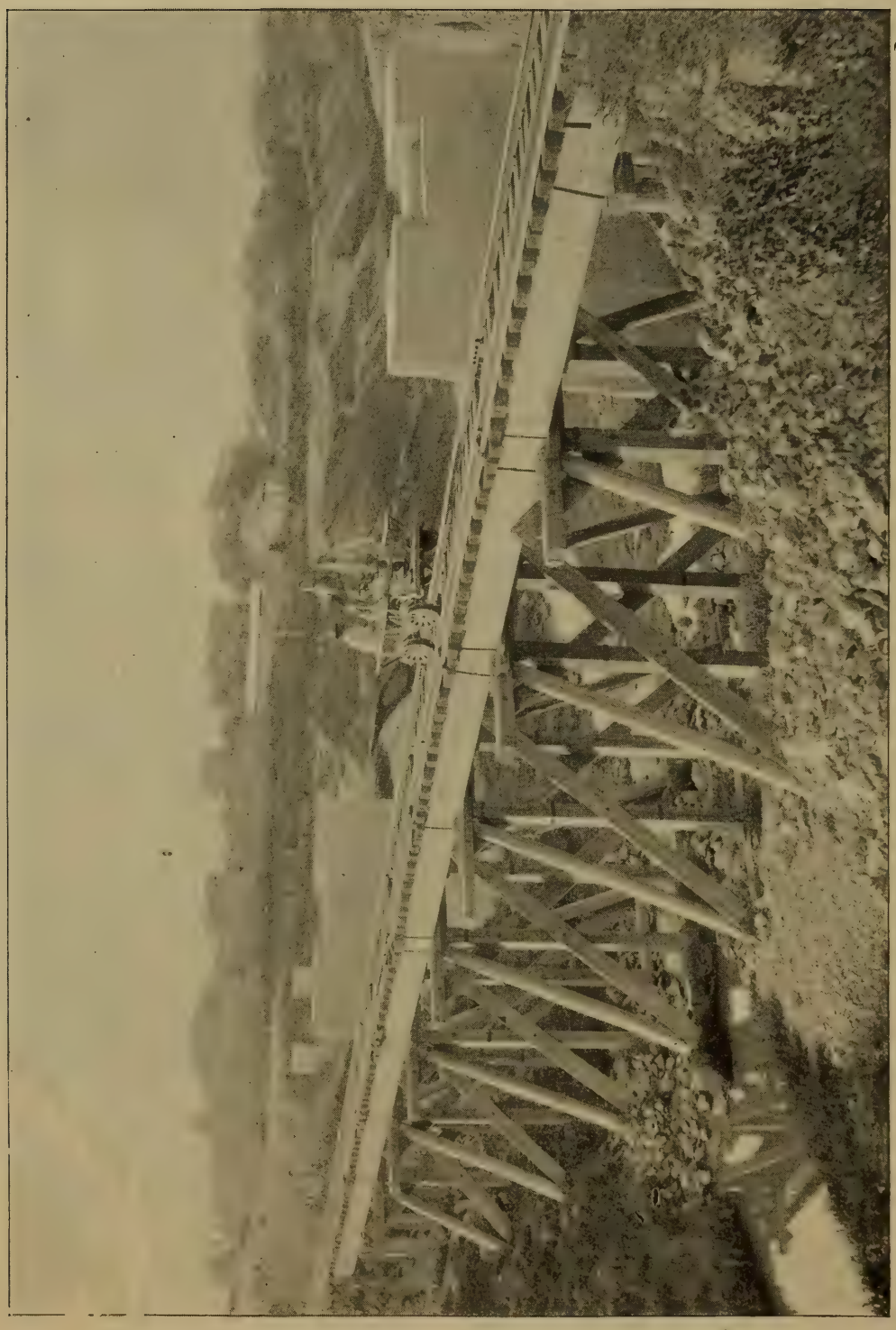
The spring work, therefore, can last only about three months, but during that time a vast multitude of workers can be got together, and any ordinary height of bank, if not of cutting, is completed. When the millet is down, earthwork may begin again and proceed until the ground is again frozen hard, for a period of perhaps another month or two. As a rule, trimming and making up only is done, or needs to be done, in the autumn, as it is essential to get the whole of the rains, —and the heavier they are, the better, —on the banks, to settle them in the most effectual manner. Moreover, survey must immediately precede the execution of earthwork or all pegs will be lost, and location survey can proceed effectually only in autumn and winter, when the 15-foot-high "Kooliang" crop is down. It is, therefore, sufficiently clear that earthwork in North China can, practically speaking, be undertaken only in spring and carried on for a short period of time. It should thus not appear extraordinary that a whole 80-mile division of railway earthwork can be, and is, completed in two or three months. To a Chinaman north of, or near, the Yellow River, any suggestion that this was an exceptional feat would fail to flatter.

In one case, that of a ten-mile branch to some stone quarries above mentioned, survey and location had, of necessity, to be done extra quickly and directly the "Kooliang" was down, and earthwork had to follow at once, being finished after the first frosts had set in, and this line had to be run over in the following spring before any rain had fallen or the hard lumps of frozen soil in the banks had melted out. Notwithstanding this, traffic was, with one week's interval, maintained through the rains, and supplies were kept up for construction work to proceed on the main line.



ERECTING A BRIDGE GIRDER AT [illegible]U LIA[illegible]G HO

Land buying is carried out as fast as location can proceed, and with a competent and sufficiently authoritative native official, having full and real authorisation from Peking, gives no trouble. The graves of the rich or powerful have



TEMPORARY BRIDGE AND CONCRETE PIERS AT MANG NIU HO

to be sedulously avoided; those of the middle or poorer classes, when on the line, are paid for at a fixed rate, and are decently removed by the families concerned. A considerable number of such removals are unavoidable in a country where each family locates its own private cemetery on such spot of ground as the "good joss man" may select.

Traffic problems in the far East tend to be recondite, and repay study. Probably the traffic survey is more important than the engineering survey in a greater ratio there than anywhere else. Freight rates and prices of commodities are cut very fine by the native, and considerations as to terminal facilities, connection with waterways, competition with waterways and roads, the travelling and other habits of the people, the effect of a proposed route on the future movement of commodities as well as the present movement, the avoidance or otherwise of octroi and transit levies, all influence the course and amount of traffic.

Even at the low rates in force in China a coolie without heavy baggage can with far less expenditure walk 100 miles, paying for food and inns, than ride, and he can do it at less than the actual working cost of hauling him. Nevertheless, railways in China under British management can be made to pay and pay handsomely, but this can be done only by using the native in large numbers and the white man at high pressure, and striking the true economic balance between moderate efficiency and honesty at low price and higher efficiency and character at a vastly higher rate.

ELECTRIC CABLE MAKING

IN GREAT BRITAIN AND ON THE CONTINENT

By a Staff Correspondent

[What is given in the following pages is supplementary, in a measure, to the article on the same subject in this magazine for October, 1900, from the pen of Mr. William Maver, Jr., a well-known cable expert. Mr. Maver, however, in that issue confined his remarks solely to the making and testing of cables in the United States, while in the present instance British and European practice is outlined.—THE EDITOR.]

CABLE-MAKING and covering machinery may be said to have been evolved more or less directly out of that utilised in the wire-rope industry; indeed, the original machinery employed in that industry is now to be seen in improved and modified form performing work in the earlier stages of electrical cable manufacture.

Insulated cables may be divided into several classes, according to the nature of the insulating sheath, whether it be gutta-percha, India rubber, fibre, paper, or other compounds too numerous to mention, and the mode of manufacture varies somewhat, according to which of these various materials is employed. It is not proposed to discuss the various merits and demerits of these several compounds, which all have their advantages and disadvantages, according to the work which they are ultimately intended to perform; suffice it to say that the first-named, viz., gutta-percha, is practically limited in its uses as an insulator to telegraph and telephone conductors and other circuits where the electrical currents to be conveyed are extremely small, whereas the other materials mentioned are universally employed for the insulation of electric light and power conductors. As regards the conductor itself, copper is the metal almost universally used, although aluminium has, of late, threatened to rival it.

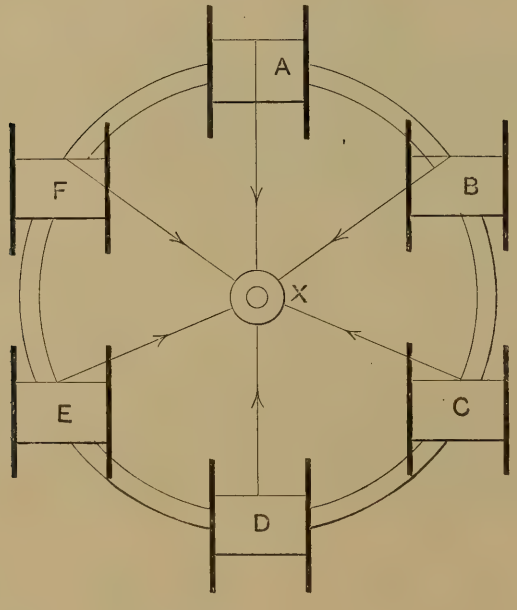


FIG. 1. THE PRINCIPLE OF THE STRANDING MACHINE

The earlier stages of cable manufacture are the concern of the wire drawer and the rubber manufacturer. Wire drawing, being a familiar process, will not be enlarged upon here, whilst rubber making, which is more or less secret, involving the mechanical and chemical mixing of various ingredients in certain quantities and proportions known only to those concerned, will also be disregarded, and the writer will pass on to cable manufacture proper, taking it for granted that the raw material, wire, India rubber, gutta-percha, etc., has been manufactured up to a certain state which leaves the wire in the shape of hanks or coils varying in size and length, and the covering material in various forms to be described later in connection with the several processes involved in its manipulation.

One of the earlier processes which

STRANDING MACHINES IN THE WORKS OF MESSRS. W. T. GLOVER & CO., TRAFFORD PARK, MANCHESTER

precedes the actual covering or insulating of a cable is that of tinning the conductor when the latter consists of copper. This consists in applying a thin film of metallic tin to the surface of the copper in order to protect the latter metal from the corrosive action of the free sulphur always present in rubber compounds. This covering of tin is applied only in cases where rubber is used as an insulator, and the process consists in drawing the wire through the contents of a series of tanks, which vary in number, according to the desired thickness of the coating.

The first tank contains a dilute acid mixture corresponding to the flux employed in soldering, and serves to procure a clean, bright, metallic surface on the wire. The second and succeeding baths contain molten tin, usually with a slight admixture of lead, to give the necessary ductility to the coat. These tanks are maintained at a fairly constant temperature by suitably arranged gas jets in order that the metal may flow freely, and oxidation of the surface is prevented by a layer of tallow or other heavy grease. After leaving the last bath the wire passes through a "snug" or die, of cotton waste or leather, which smooths down the surface and removes any superfluous metal which may adhere and be carried over. The coils of wire after tinning are well washed to remove all traces of acid, which, if left on, would, in course of time, exercise a corrosive effect upon the metal, and are then thoroughly dried in sawdust or by other suitable means.

A second important process, preceding that of covering, consists in stranding or laying the single conductors to the numb r of several into a composite conductor or strand which combines the advantage of greater cross-sectional area and consequent current-carrying capacity with those of flexibility and greater capacity for the radiation of heat, all of which are necessary adjuncts to the successful construction of a cable for electric light and power purposes where comparatively heavy currents have to be handled with a minimum loss through fall of potential, overheating, and other causes. The strands most

CABLE STRANDING BY THE ALLGEMEINE ELEKTRICITÄTS GESELLSCHAFT, BERLIN, GERMANY

commonly adopted consist of 7, 19, 37, 61, and 91 wires, and an even larger number for special purposes, such as the flexible connections between dynamo brushes, electrolytic tanks, etc., all of which call for an extra degree of flexibility to allow greater freedom of manipulation.

Stranding is effected by means of stranding machines, which are of various types and sizes, according to the nature of the work they have to perform. They are all, however, based upon a common principle, viz., that of a number of drums or bobbins, *A*, *B*, *C*, etc., Fig. 1, mounted upon a rotating carrier and feeding their contents, in the shape of single conductors, into a central die or hollow mandrel *X*, which finally closes the strand, and delivers it on to a drum placed to receive it. The drums or bobbins *A*, *B*, *C* are free to revolve on their own axes, and are severally provided with adjustable friction devices which prevent them from overrunning and allowing a sag or slack to form in the conductor as it leaves them. By an ingenious mechanical device they are all maintained in the horizontal position shown, as the carrier revolves, a necessary precaution to prevent the formation of twists and kinks in the wire as it enters the strand. The die *X* is interchangeable, and varies in size according to the diameter of the finished strand. The shaft of the carrier is hollow, and the central conductor of the strand passes through it, being fed horizontally from an extra drum at the rear end of the machine.

The "lay" of the strand or longitudinal dimension embraced by a complete turn of one wire in the strand, is regulated by varying the speed of the pull-off gear in relation to the speed of rotation of the carrier and bobbins. When the number of wires in the strand exceeds seven, *i. e*, one central wire and six encircling ones, the strand runs into layers, and each successive layer is then put on in a different direction to the foregoing one. For example, if the first layer of six wires in the seven-strand has a right-handed lay, or a twist in the direction normally taken by the hands of a clock, then the next layer of twelve wires, making up a nineteen-strand, will have a left-handed lay, or be arranged counter-clockwise. If this expedient were not resorted to the wires in the outer layers of the strand would tend to fill up the interstices between the wires of those below and thus force the lower wires out of position, besides detracting from the ultimate flexibility of the cable and reducing its total sectional area and radiation efficiency.

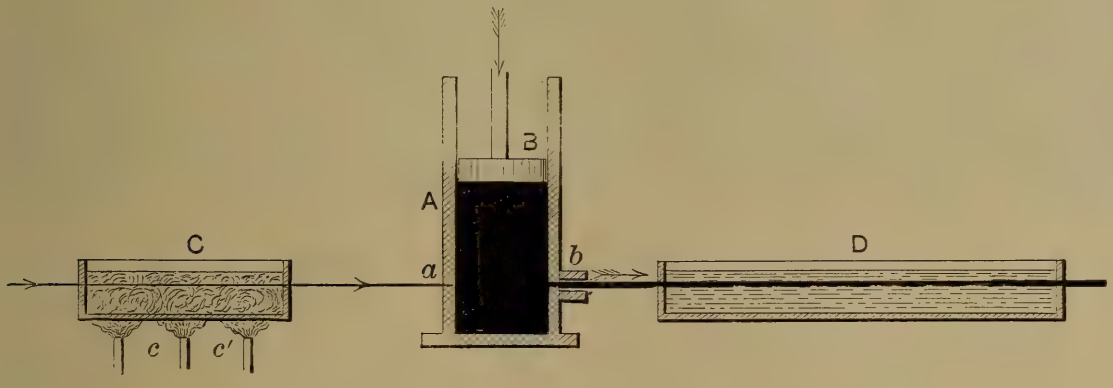
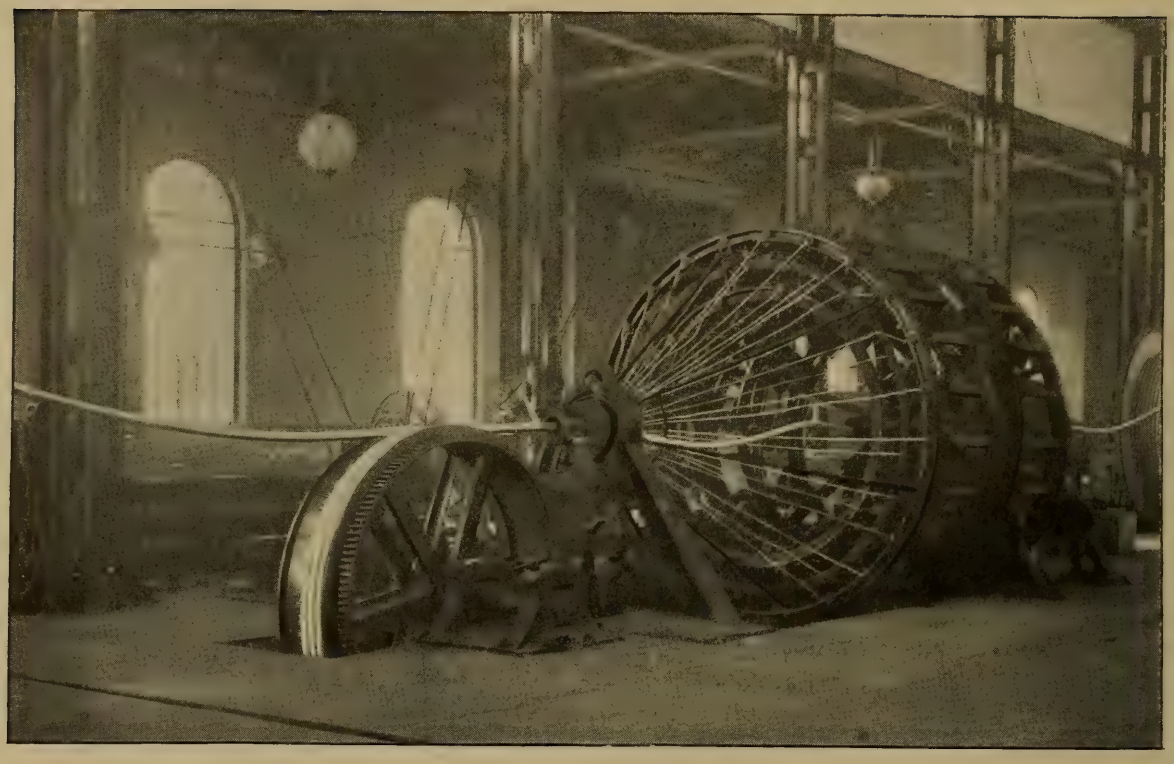


FIG. 2.—AN EARLY FORM OF GUTTA-PERCHA COVERING MACHINE

The several layers in a compound strand of 19, 37, 61, and 91 wires are frequently put on in one operation by means of suitable stranding machinery arranged tandem fashion, each carrier and its complement of bobbins revolving in an opposite direction to its immediate neighbour on either side. This device has a time-saving value, and is largely adopted in all manufactories where heavy stranding has to be done.

We now come to the actual covering or insulating of the conductor, either in



A 72 SPOOL COVERING MACHINE USED BY THE SÜDDEUTSCHE KABELWERKE AKTIEN GESELLSCHAFT, MANNHEIM, GERMANY

the form of a single wire or one of the many strands whose process of formation has just been discussed. Gutta-percha was among the earliest insulators used in this work, and, as its field of utility is somewhat limited, as before mentioned, it will be dealt with first. The earliest forms of gutta-percha covering machinery consisted, in the main, of a closed cylinder and piston *A* and *B*, Fig. 2. The walls of the cylinder were pierced at *a* and *b* to allow the passage of the conductor to be covered, which took the direction shown by the arrowheads. The aperture *b* was fitted with a die bored to the external diameter of the insulated core, and the cylinder *A* was filled with gutta-percha reduced to a plastic state by judicious heating. Pressure was applied to the piston *B*, causing the gutta-percha to exude through the die *b* at a similar rate to the passage of the wire itself, which constituted the moving axis of the die. The trough *C* contained molten Chatterton's compound, a combination consisting of one part Stockholm tar, one part resin, and three parts gutta-percha. This compound was maintained in a molten state by the gas jets *c*, *c'*. The object of its presence in the shape of a thin film on the wire before covering was to provide an adhesive layer, and thus effect a sound junction between the gutta-percha and the copper core. A layer of this compound was similarly introduced between successive layers of the gutta-percha, with the same end in view, viz., that of securing a homogeneous coating. A shallow trough of cold water *D*, a few hundred yards or even more in length, served to cool the gutta-percha as it left the die, and thus toughen it before the conductor had an opportunity of sinking through the soft material by virtue of its own weight.

Some trouble was experienced in the manufacture of gutta-percha covering by this device, owing to the presence of air which it was found almost impossible to totally exclude, and which found its way, in the form of minute bubbles, into the substance of the insulating sheath, where its presence, especially in the insulation of submarine cables, caused considerable annoyance. This drawback is eliminated in the modern gutta-percha covering machine, which is the

outcome of the inventive genius of Mr. Matthew Gray, and was patented in 1879. By this device, the principle of which is roughly indicated in Fig. 3, air is totally excluded. A pair of rollers, *A* and *B*, grip the pure gutta-percha in the form of sheet, and feed it into the enclosed chamber *C*, whence it is fed forward by the species of Archimedean screw *D* to the die *E*, from which it emerges around the conductor as a travelling axis. A subsequent patent lodged by Mr. Ludwig Loeffler in 1880 provides for the simultaneous application of several coats of gutta-percha to a conductor without the necessity for an intervening film of Chatterton's compound. This is secured by a species of multiple delivery box, consisting of several concentric and adjoining dies gradually increasing in size as they approach the exterior, and which are all in connection with the gutta-percha receiver, and consequently receive a simultaneous supply of the latter under pressure of the screw *D*.

A similar system of application is adopted, especially in Continental practice, with some of the inferior rubber compounds. The more a rubber compound is adulterated with foreign elements, the nearer it approaches the consistency of freshly made putty, and this fact was, at any rate in the early days, duly made use of by Continental manufacturers as affording a ready and inexpensive means of applying the rubber coating. The process certainly yields an even and homogeneous insulation, and one which can be placed on the market at a comparatively low cost, but rubber-covered conductors insulated

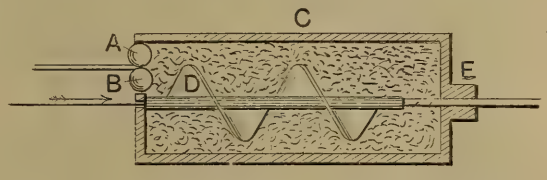
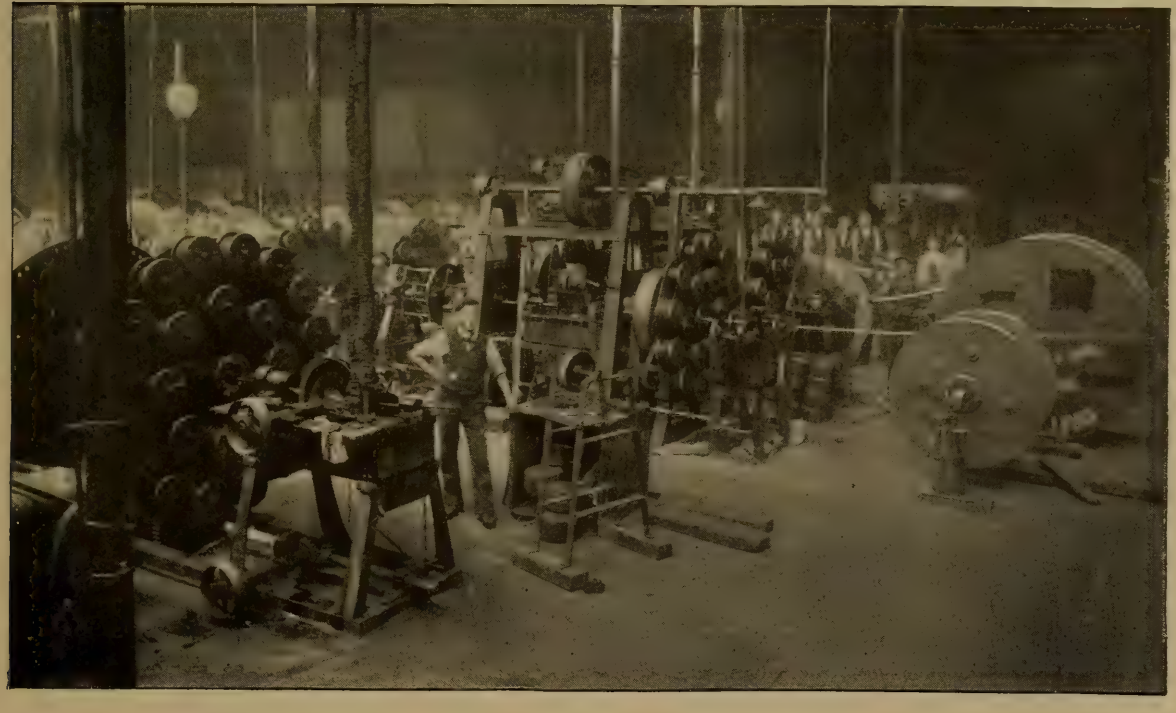


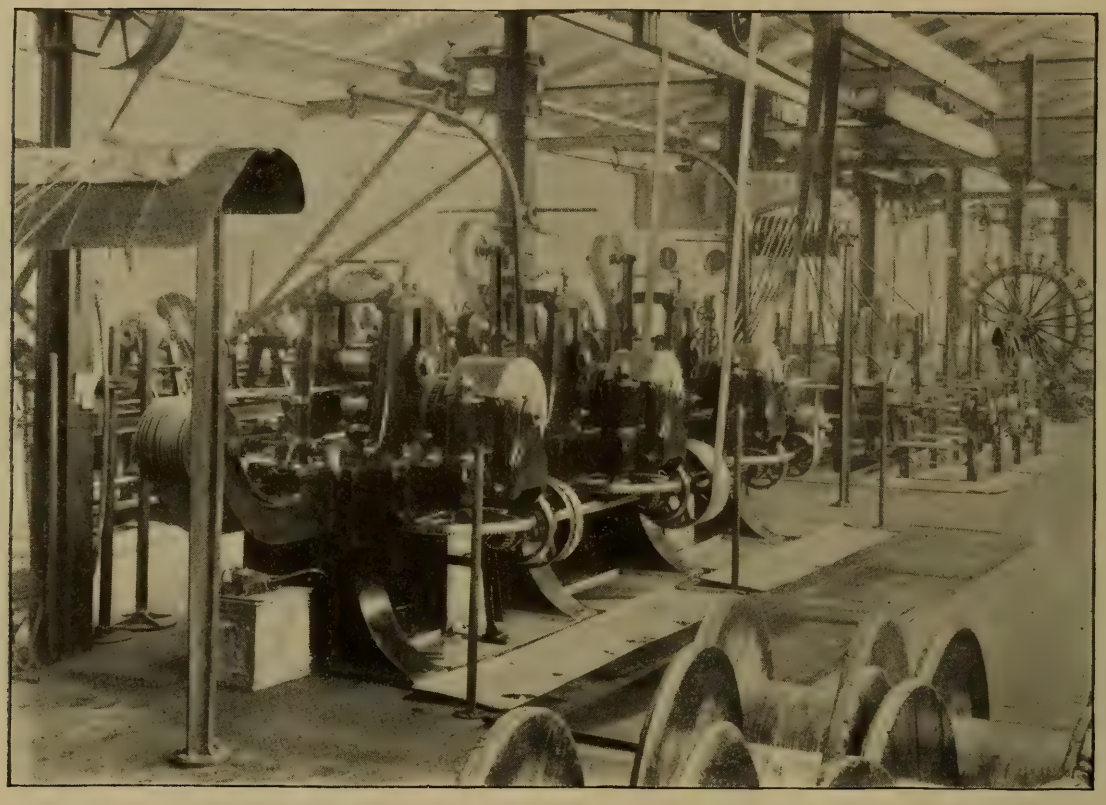
FIG 3.—A MODERN GUTTA-PERCHA COVERING MACHINE

in this manner are not to be depended upon, so far as their insulation is concerned, and should be employed only on low-voltage circuits.

The manufacture of a rubber-insulated cable as commonly practised by British makers consists, in the main, of three distinct applications, so far as the rubber itself is concerned, these three grades being determined by the nature



CABLING SHOP OF THE BRITISH INSULATED WIRE COMPANY, PRESCOT



RUBBER-COVERING MACHINERY AT THE WORKS OF THE TELEGRAPH MFG. CO., LTD., HELSBY. NEAR WARRINGTON

of the coating, which is a composite one. Analysing a typical sample of rubber-covered cable, we find next to the conductor a thin coat of pure Para rubber, which determines, by its thickness and homogeneity, the ultimate electrical resistance of the insulation. Next comes an intermediate layer of compound rubber, which has no sulphur in its constitution and is known as the "separator." The object of this layer is to take up and incorporate in itself, during the process of vulcanisation, the excess of sulphur in the outer surrounding layer of compound rubber, which is termed the "jacket," and thus prevent it from reaching the metallic conductor, to the detriment of the latter.

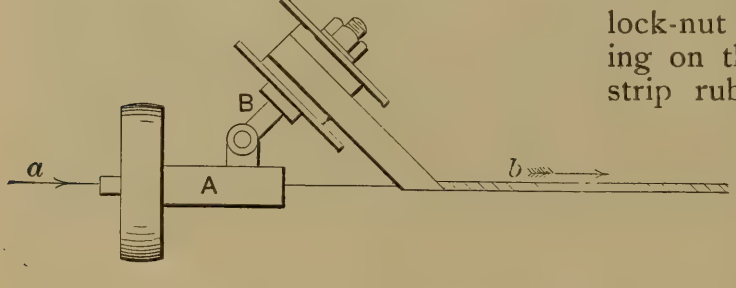
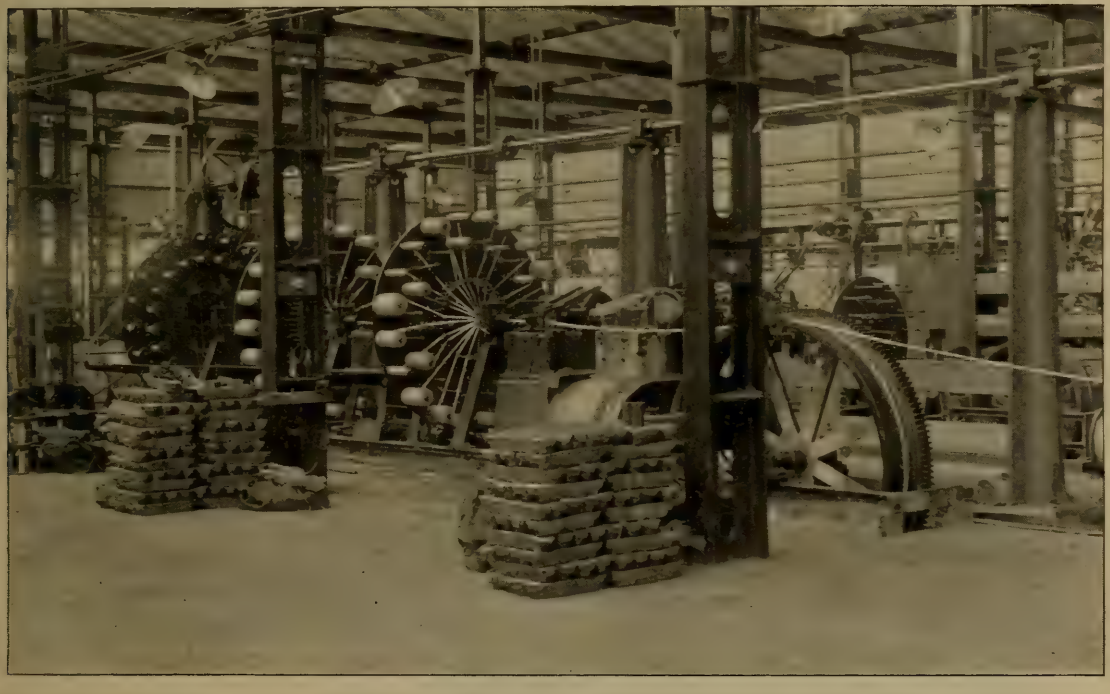


FIG. 4.—LAPPING A CONDUCTOR WITH RUBBER

As regards the mode of applying these three coats, the rubber, pure and compound, as received from the manufacturer, is in the form of long sheets, rolled upon a wooden mandrel, centred at its extremities for the purpose of mounting in a lathe or cutting machine. The roll thus mounted is cut, by means of a knife-shaped tool, into sections of varying width, according to the size of the conductor to be covered. The strips thus formed are then applied to the conductor by either of the following methods. The first, known as "lapping," consists in passing the conductor to be covered through a hollow mandrel *A*, Fig. 4, attached to which, at an angle capable of adjustment, is a spindle and bobbin carrier *B*, controlled by a lock-nut and friction washer, and carrying on the bobbin one of the reels of strip rubber mentioned above. The mandrel and its attached bobbin revolve, at a certain predetermined rate, according to the degree of "lap" required, relatively to the speed of passage of the con-

ductor *a b*, which is operated by suitable pull-off gear.

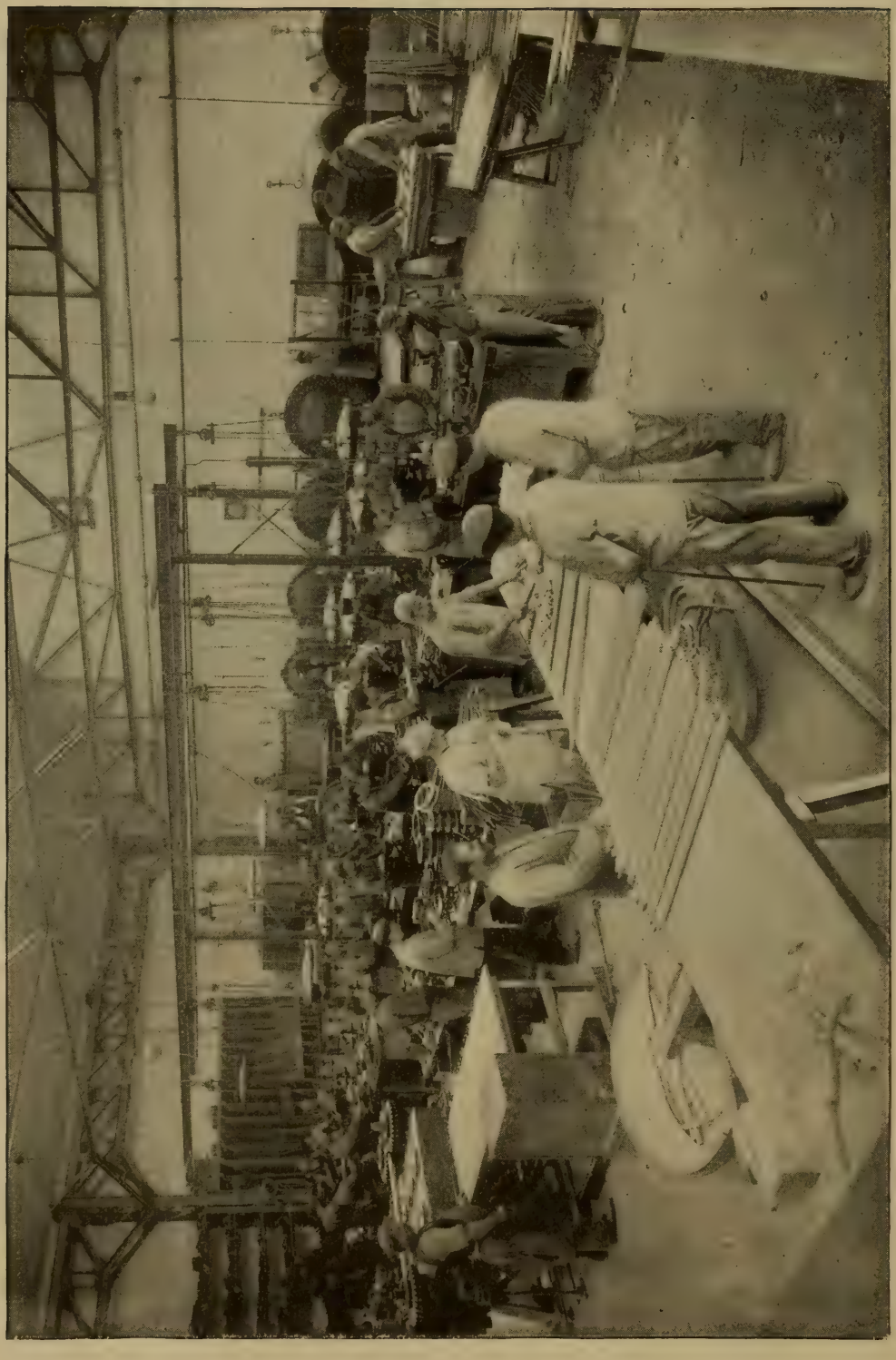
In applying pure Para strip rubber by this method, considerable friction is maintained by means of the attached lock-nut and washer, between the bobbin *B* and its spindle, in order to stretch the rubber as it meets the conductor and so reduce it to the necessary thinness, besides imparting a binding action by reason of the inherent elasticity of the material which causes it to form a close and homogeneous coat upon the conductor. Compound rubbers, in the shape of separator and jacket, may also bins, in alternative opposite directions. The "lapping" system of covering is seldom adopted at the present day for the application of such compound rubbers as the separator and jacket, being somewhat slow and expensive as compared with the more general system known as "longitudinal compression." This system depends for an efficient joint between the various rubber strips forming the crude insulation upon that property of freshly-cut, clean rubber surfaces, which causes them to adhere, and, as it were, incorporate, one with the other when brought into immediate



SERVING MACHINE IN THE WORKS OF THE TELEGRAPH MFG CO., LTD.

be applied in like manner, under a less degree of friction, which is, nevertheless, sufficient to cause the spirals to bed down close upon one another and form a firm, solid layer. The separator is lapped on in the opposite direction to the preceding coat of pure rubber, and a similar plan is adopted, as in stranding, with the subsequent layers, which are given a right and left-handed lay alternately. These several lapping operations are frequently performed in one operation on a single machine, the several "heads" being arranged tandem fashion, and so geared as to revolve, with their attached bob-

contact. This useful principle is practically applied to modern cable-covering machinery in the following manner:—In Fig. 5, *A B* represent two accurately turned hard-steel rolls about 6 inches in diameter, placed in contact as shown, geared together through the medium of their axes and attached toothed-wheels, in such a manner as to revolve in opposite directions like the rollers of the domestic mangle. These rolls are semi-circularly grooved, as shown, around their peripheries, in such a manner as to form, when placed in position together, a circle, equal in diameter to the insulated conductor. The con-



VULCANISING AND HARD RUBBER DEPARTMENT. THE ALLGEMEINE ELEKTRICITATS GESELLSCHAFT, BERLIN

ductor itself, *a b*, is passed longitudinally through the centre of this circular aperture, in conjunction with two strips of compound rubber, one above, and the other below, fed from the bobbins *c d* arranged just behind the active rolls *A B*. The latter revolve in the direction indicated by the arrows, at a peripheral speed equal to the linear speed of the conductor, and, carrying the rubber strips along with them, close the latter around the conductor, and, finally, at the meeting point, cut off the superfluous rubber by dint of their accurately turned edges, leaving a perfect longitudinal seam along either side of the covered conductor. The superfluous rubber is fed off into a receptacle ahead of the rolls *A B*, placed to receive it, and can be remanufactured and used over again, so that there is no waste.

One groove only is shown in Fig. 5 for the sake of clearness; but, as a rule, two, three, and in the smaller sizes of cable and single conductors, six, or even more grooves are turned in the same pair of rolls, so that a corresponding number of conductors can be dealt with in one and the same operation, with a considerable saving in time and material. As in the previous system, these sets of rolls are usually arranged in tandem, so that two or more layers may be applied simultaneously.

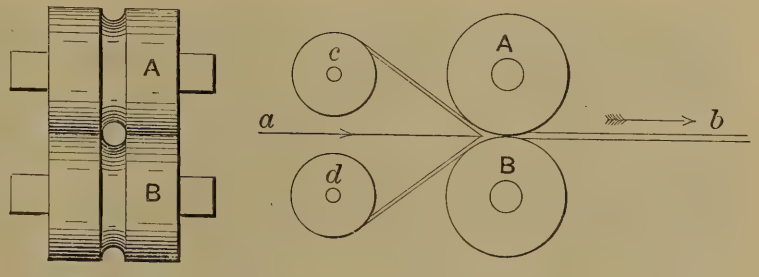


FIG. 5.—RUBBER COVERING BY LONGITUDINAL COMPRESSION

The next operation to be noted in connection with the manufacture of rubber-covered cables is that of "taping," or the application of a spiral, canvas, waterproof tape to the surface of the covered conductor, its object being to act as a binder to the rubber coatings and secure them in position during the process of vulcanising, as well as to prevent contiguous turns on the drum or bobbin from adhering to one another by reason of the previously mentioned property of freshly-cut rubber surfaces. This waterproof tape is made in the form of sheets by spreading a layer of compound rubber solution upon canvas, the surplus solution being "struck" off by means of a fixed straight-edge under which the sheet passes. The solvents in the solution are ultimately expelled by the aid of heat generated in a steam plate over which the prepared canvas is caused to pass.

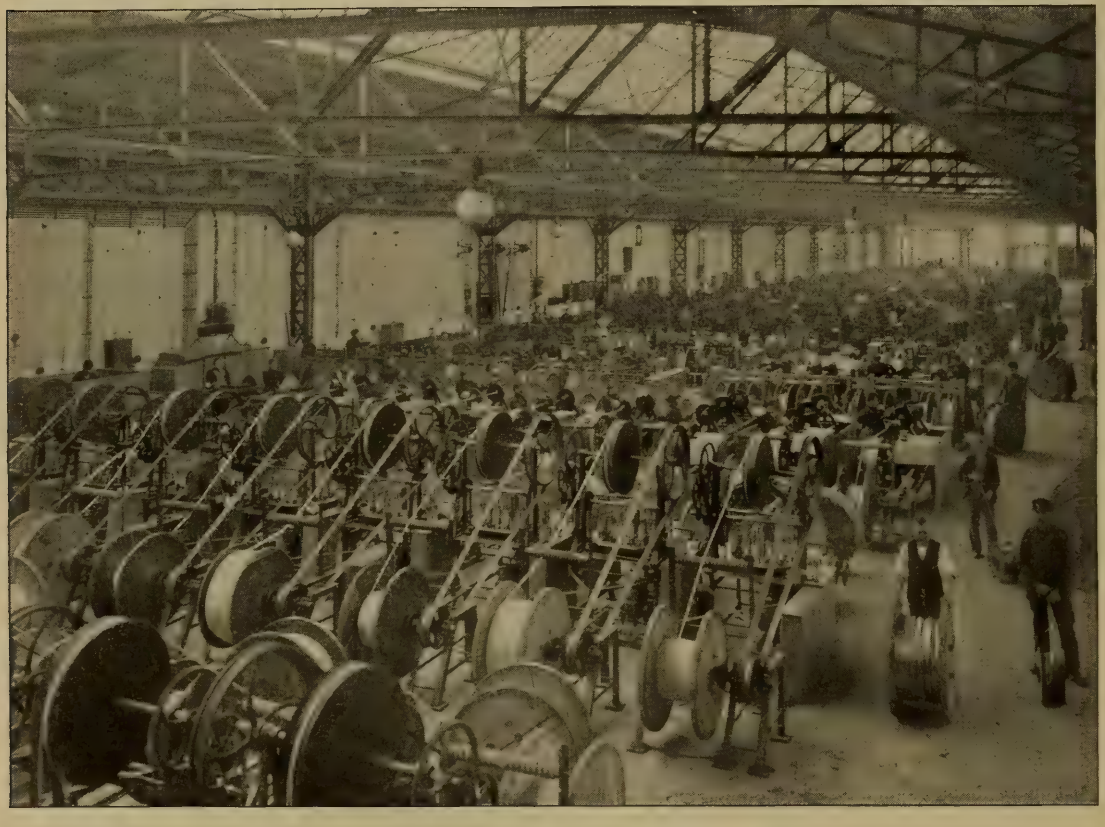
The material thus prepared is then made up into a roll upon a suitable mandrel, and is cut by machinery into tapes of various widths. These tapes are applied to the rubber-covered core by a machine having a similar action to that of the rubber lapping machines previously described, the only difference being that a slotted tubular extension is added to the fore part of the revolving mandrel, to act as a guide to the tape and prevent it from becoming twisted or distorted as it approaches the periphery of the core to be covered. One layer of tape is generally considered sufficient for the purpose, especially in the smaller sizes; but, if considered necessary,—in some cases to form a firm, even bed for the reception of an ultimate lead-sheathing or armouring of iron wires,—two layers are applied, the second coating being given a lay in the opposite direction to the preceding one.

After having received its coat, or coats, of waterproof tape in the above manner, the rubber-covered conductor is ready to undergo vulcanising, which is effected as follows:—The core to be vulcanised is carefully coiled upon metal drums or bobbins which have been previously padded with some yielding material, such, for instance, as several thicknesses of canvas tape, in order that the soft rubber coating may not be injured by being indented. The coiling

is effected in as few layers as possible, in order that there may be as little weight or pressure exerted upon the inner spirals as the capacity of the drum will allow; if these latter be subjected to excessive pressure, the rubber tends to flatten, thus throwing the conductor out of centre.

Having been carefully coiled on the bobbins and secured in place by suitable lashings, the extremities are hermetically sealed by a rubber binding, to the total exclusion of moisture, and the whole bobbin is placed bodily into the vulcanising receiver,—a massive cast-iron cylinder of the requisite dimensions to enable it to contain the largest drum of cable likely to require vulcanising. This cylinder is fitted with steam attachments, blow-off and drain cocks, and a pressure gauge, and is also provided with a recess in its cover to contain a special thermometer, recording temperatures up to three or four hundred degrees Fahrenheit. The cover is flanged and detachable, being secured in position pending the process by a number of bolts and nuts, the joint being made steam-tight by suitable packing introduced between the flanges. The bobbins having been placed in position, the cover is bolted on, and steam is allowed to enter. The pressure of the latter is raised to a certain predetermined point as indicated on the pressure gauge, and the temperature also is regulated as nearly as possible within certain preconceived limits.

The application is continued for several hours, fresh steam being admitted from time to time in order to compensate for condensation. At the expiration of a stated period the steam is blown off, and the cover removed; the contents are then taken out and allowed to cool previous to immersion in a tank of water for the purpose of testing the electrical properties of the insulation. The data respecting steam pressure, temperature, and time involved in the above operation vary considerably with the nature of the cable undergoing vulcanisation, and are largely the result of



BRAIDING MACHINES USED BY THE ALLGEMEINE ELEKTRICITÄTS GESELLSCHAFT, BERLIN, GERMANY

experience gained by those engaged in the industry.

Having undergone the various testing processes which do not come within the province of this article, the core is ready for the several finishing processes, viz., braiding, compounding, lead-covering, armouring, serving with jute, etc., each of which we will deal with in turn. Braiding is a species of finish given to a cable, chiefly in the smaller sizes, which is to be used for interior work, such as the electric light and power wiring in buildings, and similar situations where the cable is mechanically protected by an encircling trench, conduit or tube. It consists in surrounding the core with a woven or braided sheath of jute or cotton, the former being employed for the larger and the latter for the smaller sizes of conductor. The process of application is one of the slowest in the whole series of stages involved in cable manufacture, and necessitates an extensive plant to cope with the supply of material from single machines performing the preceding processes.

The braiding machine is a somewhat complicated mechanism, consisting of a series of vertical spindles, carrying the wooden spools of jute or cotton, as the case may be, intergeared with one another, by means of a number of pinions, in such a manner as to pass one another alternately on the inside and outside whilst rotating, in two distinct sets, in opposite directions. The machinery is almost automatic, so much so, indeed, that one person can look after a series of them, the only attention required being that involved in replacing and splicing from time to time, a spool of jute or cotton as it becomes exhausted.

The process subsequent to the above-described one of braiding is known as compounding, and consists in impregnating the jute or cotton braid with a preservative compound which shall at the same time assume an external polish and colour, and so impart a selective and glossy finish to the cable. The compounds adopted for the purpose vary considerably in their composition, but usually consist of a beeswax base, with which are incorporated various ingredients and pigments, the prevailing tones for the latter being black and red, the selective colours for the negative and positive poles of a circuit. The impregnating is effected by drawing the braided conductor through a series of tanks containing these various compounds in a molten state, the necessary heat being obtained by the use of steam jackets. The first tank starts the impregnation of the fibrous braid, whilst the last imparts a final coat. On leaving the last tank, the cable passes through a die of leather or rubber, which removes the superfluous compound from its surface, and finally through a dry pad of leather or canvas, usually applied by hand, which produces a final polish on the otherwise finished cable.

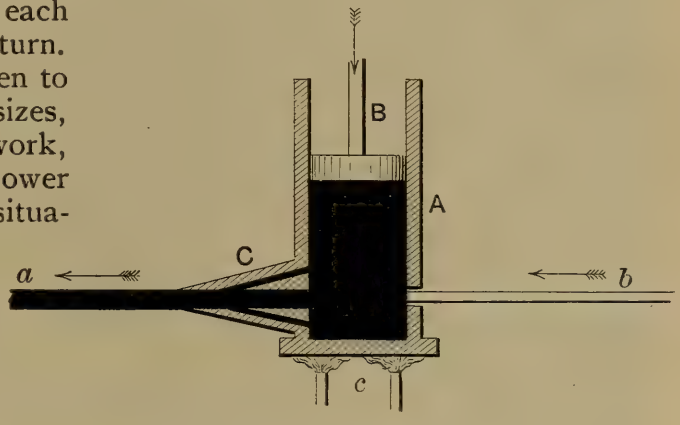


FIG 6.—A LEAD PRESS DIAGRAM

Lead covering or sheathing a cable consists in applying an even and homogeneous layer of lead to the exterior of the insulated core, as a general rule next to the canvas tape. The lead coating varies in thickness with the size of the cable to be covered, and other details, and its province is to act as an air-tight mechanical protection to the cable and thus render it suitable for laying directly in the ground without any additional preservative in the shape of conduits or trenches. A small percentage of tin is usually alloyed with the lead in order to combat the corrosive action of the surrounding earths.

The application of the metal sheathing to the exterior of the insulated core

LEAD PRESSES

is effected by the aid of a lead press similar to that used in the manufacture of lead tubing. It is a hydraulic press, mounted on substantial foundations, and fed from a separate pump, or series of pumps. The principle of the device is illustrated in Fig. 6, in which *A* represents the cylinder or "container," filled with lead, maintained in a semi-plastic state by the gas burners *c*; *B* is the hydraulic ram which exerts a pressure upon the soft mass of metal in *A*, and forces it out through the egress die *C*, around the core to be covered, *a b*, which passes through the press in the direction indicated by the arrows. The die *C* is interchangeable, and its size can be varied to suit the diameter of the cable to be covered.

An external finish is sometimes given to lead-covered cables by serving them with a layer of tarred jute which is afterwards impregnated with a bituminous compound to act as a preservative and binder. This serving and compounding is often effected in one operation by means of a special machine fitted with the necessary heads, arranged tandem fashion. The "serving" head consists usually of a disc or frame *A*, Fig. 7, carrying a number of spindles *a*, *b*, *c*, etc., arranged at right angles to one of its faces, and on which are fitted the wooden spools, each carrying a strand of the jute employed in serving.

These several strands are led radially down after the manner of the wires in a stranding machine, through eyelets 1, 2, 3, etc., which guide them as they leave the bobbin and so prevent them from becoming entangled. From the eyelets the strands pass on to a central die or snug *F*, with the edges of its internal bore rounded, which finally closes them around the cable *B C* as it passes through, in the direction indicated by the arrow. The cable thus served with jute then passes on and around the grooved pulley *E*, which revolves, for the greater portion of its diameter, in the trough *D*. This is steam-jacketed, and contains hot molten compound to impregnate the jute serving. As it finally leaves this tank and pulley the cable is usually whitewashed on its outer surface in order to prevent contiguous turns on the receiving drum from sticking together through the medium of the hot compound which retains its heat for a considerable period. Such a serving of jute as the one above described, is usu-

ally applied to a cable both before and after armouring,—in the first instance to form a bed or foundation to receive the subsequent armour, and in the second, to form a protective and weather proof coating over and above the armour itself, both servings being thoroughly impregnated with compound in the manner described above.

The process of armouring a cable may be sub-divided under two heads, according to the nature of the armour employed, whether spiral steel or iron wires completely surrounding the cable, or a broad steel tape, lapped on in two layers, the latter of which serves to cover the butt joints between the spirals of the one beneath. The first method is effected in a machine similar to that used for stranding; it is, in point of fact, a stranding machine, the bobbins on the carrier being filled with galvanised iron or steel wires, and the cable to be armoured being passed through the hollow mandrel from the rear of the machine, like the central wire of a strand, as before described. The armour is finally closed by a die, and subsequently layers are put on with an opposite lay to the preceding ones. When a bobbin runs out a fresh one is inserted in its place, and a brazed joint is made in the wire.

ation by two "heads" similar to that illustrated in Fig. 4, arranged tandem fashion, and so geared as to revolve in opposite directions respectively, thus imparting a right and left-handed lay to the two steel tapes. An armouring of steel tape such as the one described is finished by an outer serving of jute applied as described in a preceding paragraph and subsequently impregnated with a preservative compound.

Fibrous insulated cables usually consist of a plain, untinned copper strand served with several layers of jute, each in an opposite direction to the preceding one. The serving is effected in a serving machine, such as the one already described, and each layer is thoroughly impregnated with an insulating compound, the composition of which varies enormously with different manufacturers. In order to ensure a thorough saturation of the fibres composing the jute, the whole cable is sometimes immersed bodily in a large tank of the compound in question, and subjected to considerable heat for an appreciable period in order to ensure the expulsion of all moisture and the absolute saturation of the jute. Cables insulated in this manner are finally sheathed with lead, without which their insulating

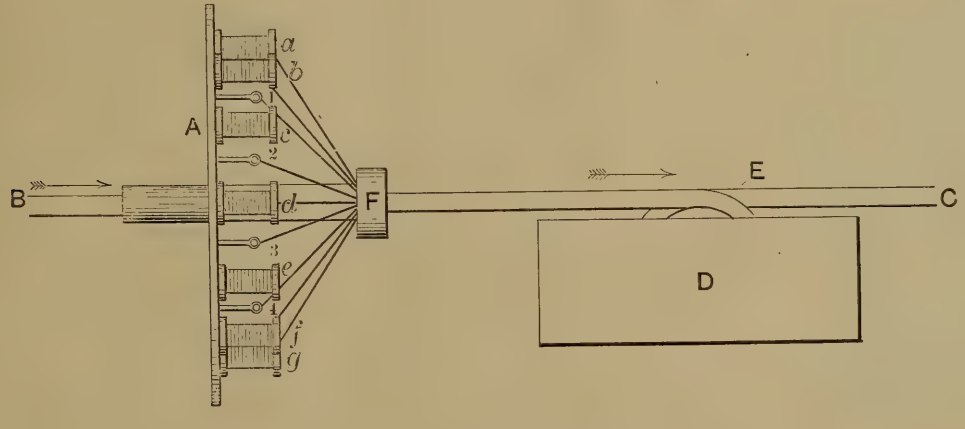


FIG. 7.—HOW LEAD COVERED CABLES ARE SERVED WITH JUTE

The armouring of a cable with steel tape is effected in a machine similar to that shown in Fig. 4, used for rubber lapping, except that it is of a heavier build, and that the bobbins are filled with steel tape in place of rubber strip. The two layers are applied in one oper-

properties would be of little avail, since all fibrous matter is naturally extremely susceptible to moisture, the presence of which, even in minute quantities, means ruination to the insulation of the cable. For this reason the lead coating must be absolutely homogeneous and free

from pinholes or flaws, which are soon rendered apparent, where they exist, by the twenty-four hours' submersion under water and subsequent electrical tests to which the cables are subjected.

Paper-insulated cables are also covered in a machine fitted with "heads" similar to the one illustrated in Fig. 4, the paper being applied, not too tightly, in the form of several layers of strip or tape, lapped, as before, in opposite directions. The paper is subsequently impregnated by immersion in an insulating compound of an oily nature, and, like fibrous insulated cables, receives a final homogeneous sheathing of lead.

In dry-core paper cables, such as the multiple ones employed for underground telephone circuits, the paper, in the form of strip, is passed, together with the copper wire to be covered, through a die, which folds or wraps it loosely around the conductor. The paper, in this case, is not impregnated with any compound, but is thoroughly dried, and the wires, thus covered, are made up, to certain specified numbers, in a multiple wire cable which is subsequently lead-sheathed, the sheathing being provided, in certain cases, with devices at its extremities for producing a constant or periodical circulation of dry air through the mass or interstices of the cable proper. In this manner the insulation of the various wires composing it is kept up to the requisite limit, and moisture, so detrimental to insulation of any kind, is excluded.

A NEW WORKING DAY IN BRITISH SHOPS

A PROPOSED BENEFIT TO BOTH MASTERS AND MEN

By Joseph Horner

THERE is a feeling, growing in strength and intensity, that the venerable British practice of beginning factory work at six o'clock in the morning ought to be superseded by a more sensible arrangement. If, in giving his views on this matter, the writer speaks strongly, extenuating circumstances are that his duties during a large portion of his life have involved the six o'clock start. From a lengthy experience, both as workman and foreman, he is prepared to assert without hesitation that while the first hours of work should be the best and brightest and the most productive, yet the time between 6 o'clock and 8.30 in the factory is now by far the most wasteful portion of the day. In these observations it is not proposed to discuss the question of reduction of hours which, in the face of increasing foreign competition, does not yet appear practicable, but only that of their readjustment, with a view to make the early morning's work more profitable to the employers and more congenial to the men,—conditions that are inseparably united.

The losses which are incidental to the six o'clock start are numerous. But they result mainly from the low vitality of the men, the effects of which are apparent in many ways; from conditions incidental to commencing work so early, particularly in winter time; the use of artificial light; the losses of quarter and half hours, and quarter days; and those due to the intermission for breakfast.

Take first the question of vital energy, which is the fundamental one! The threadbare adage "Early to bed" is out of place in modern life. Its application lies properly in a simple agricultural community, but it is responsible for much misery in a manufacturing age, and in urban life. The problem is not one of sentiment at all; it does not touch the question of idleness or of industry, but it is just one of physiology pure and simple,—of the conservation of energy of the human machine. There is no virtue in mere early rising. When practised occasionally it is exhilarating, —the early cycle or swim in the summer morning, or the early spell of work when all the world is quiet and a long day has to be got through; but these do not come in the same category with the factory life, year in, year out, which is monotonous and depressing. "Early rising," said a wag, "makes one conceited all the morning, and stupid all the afternoon." It does not even do so much for the factory hand, for he begins in exhaustion, and warms to his work only as the day wears on.

Physicians and physiologists know that the expenditure of vital energy must be balanced by recuperation; otherwise physical deterioration will result. Early rising demands early rest. But few people who live in cities can obtain this, for noise prevents it and city habits interfere with it. And thus the early risers in cities do not obtain the needful early rest as their agricultural brethren do. Hence their nights are too short; the candle is burnt at both ends; and physical deterioration and early loss of vitality result.

Many men as they get into middle life adopt the only sensible course, seeing that the retention of their situation depends on keeping good time. They can no longer do without a proper amount of sleep, and so they smoke a pipe or two and go straight to bed, at eight, or nine o'clock. Some men also can manage with less sleep than others, and go on for long periods with little or no apparent deterioration. They acquire the habit, a very mechanical one, of early rising, because they must rise or lose their jobs; but it leaves its effects in lowered stamina, and in comparative dullness of intellect. However, so much shop work now is purely repetitive that dull men are able to crawl through the days and turn out fair results. But the intellectual sacrifice is great; work and sleep alone bound the horizons of these lives. These dull mechanical "hands" are not the class who will fill the breach in the trying competitive struggles with which British industry is menaced.

Insufficient rest is, therefore, the principal cause of the rapid consumption of the workman's energy, and explains why he is an old man at fifty. "Natural decay" is given as the cause of death of many a one between fifty and sixty,—an age when the intellectual worker should be in fullest vigour, and doing his best work. A valuable animal even is allowed an amount of rest suited to its constitution. Mark the difference between the cab horse and the high-stepper!

The idea which underlies the supposed necessity in British shops of the six o'clock start is, that a long day's work is secured; that if men begin at six they will do one hour's work more than if they commenced at seven; two hours' more than if the factory were opened at eight. By parity of reasoning it would be better to commence work at four or five o'clock in the morning! And if one section of the factory is opened at six, why not all? Draughtsmen, and clerks, and managers all should begin at the same time, to crowd work into the early part of the day. Principals, too, should redeem the wasted hours which they lose by not coming down until ten o'clock.

But in truth if the entire works and offices, including the principals, commenced together at six o'clock, the waste of energy would soon be apparent and the system would be doomed. If masters were always in their shops at six, moving about among the men, they would see that this early work is, as a rule, the most unproductive in the day. Those who make a casual early visit once in a moon to their works just to wake up the men and the foremen,

might as well save themselves the trouble for aught they learn thereby. They do not see the many leakages that go on, and neither are they qualified by experience to estimate the subtle differences between the men in those early hours and those who start work under better physiological conditions. In these flying visits they see only that time is "put in," and time instead of energy is the common measure of work done in the factory. Very often the writer has observed that men, after losing quarters, have got through more work in the day than others who commenced at six o'clock. The loss of time in quarter days,—"knocking off corners,"—is obvious; but energy losses do not show directly in the books, nor are they always apparent to those who suffer thereby.

Nor does the mischief consist alone in broken rest. Early rising carries with it exhausting conditions. Men are hungry, and slack in consequence of going out into the raw cold without food or warm drink in the stomach, and having to work thus for two hours and a half before breaking fast. Often they get wet, and stand in wet clothes and boots without the fortifying influence afforded by food at the proper time.

The darkness of winter mornings favours skulking, to which the badly lighted state of many shops is favourable. Men have to hurry to get inside the gates by time. Then opportunities are taken to lace up boots, and finish a too hasty toilet, perhaps to surreptitiously warm a cup of coffee, and to rub and warm chilled hands and limbs. Work is nearly always slack before breakfast owing to the raw environment, for well-warmed shops are as yet exceptional in Great Britain. These things are necessarily winked at; but if a foreman or manager appear, the men are alive for the time, and put on a spurt which does not last.

The time sacrificed in any firm by the loss of quarters is very great, especially in winter. Quarter and half hours are generally allowed in order to avoid the greater loss of quarter days, and advantage is freely taken of them. They make up, in all, a very big total in the number of hours lost in the year from this cause alone. To fine men or discharge them does not stop the evil. Nor does the drastic measure of taking off their checks for the day, which in some cases has had the effect of disorganising the work of an entire department for the day.

Men often lose quarters merely in consequence of the nervous fear of oversleeping. If one could fall asleep at once, and not wake until morning, short sleep would be refreshing; but fear of "losing a quarter,"—the workman's terror,—often wakes a man several times in the night to look at the clock. Then when the proper hour comes for rising, Nature asserts herself and gives sound sleep. Men do not lose time, which is a money loss, through pure cussedness, but because they can't help it. Even the loud alarum fails to wake always when it is heard so often, and a moment's indulgence in bed after the "knocker-up" has called is frequently fatal.

And quarters lost hit the employer as hard as the man; for a part of his work is stopped, yet the machinery has to run all the same. The work of some of his men is also thrown out of gear, as that of the smith, or his drummer, the riveter, or his hammerman; that of mates on the same job is hindered, that of moulders dependent on pattern makers, of fitters on machinists, and so forth.

Nor does the loss end even there. Many and many a time have men, when disgusted at losing a quarter,—perhaps after having run down late, to find the gates just closed,—remained out for a day's booze, which does not always end with the day. Or, again, plodding men, with lowered vitality consequent on the strain of keeping good time for many successive days, have to absent themselves for a day or more, to recuperate.

The break for breakfast may seem a small matter, but ask any foreman or manager of experience, and he will tell you that the break for any meal involves many leakages when hundreds of men

are employed, which leakages figure up considerably more than the mere time allowed for the meal. And the break for breakfast is more wasteful than that for dinner, for various reasons.

This waste is apparent only to those who have an intimate acquaintance with factory life. Work always slackens for some time before knocking off. Even the men may not be always conscious of this; it arises from a lassitude, an expectancy, and results in a "marking of time." It is more apparent, too, in winter than in summer. In winter the day is just breaking, and the light is beginning to struggle in; it seems much colder then than it did earlier in the morning. It is useless to try and quicken men's efforts under such unfavourable conditions. The foremen have no heart for it; they feel little better themselves. The human machine has run down, and work is inevitably unprofitable then.

And after breakfast work does not start on the minute; a good swing is not got up for several minutes. Some shops are situated a long way from the time office, and then coats have to be removed and changes made before work can be again started. There is always, too, some slackness for a little time after meals, more in some shops than in others; it is more evident in very hot or very cold weather than in temperate; more in shops badly warmed and ventilated than in those where the comfort of the men is studied.

We may consider two alternatives to the commencement of work at six o'clock. Each includes taking breakfast at home first. The writer would suggest 7 or 7.30 o'clock as suitable hours for beginning work. For reasons to be presently noted the 7.30 start seems the better solution; 7 oclock seems rather too early, and a start at 8 o'clock would prolong the day more into the evening than any men would care for, and would make overtime, when worked, very late also. In considering this problem we have to remember that the late start is complicated by the Saturday half-holiday which must not be touched, so that it is not a question of working nine hours every day, but of working more than nine on five days, in order to shorten the sixth day by the half-holiday, which is now a recognised institution in the factory. This reduces the Saturday's work to six and one-half, which would be too much without a break, and adds a half hour to the nominal nine hours of the other five days. The problem, therefore, is how to make the starting time later, and divide nine and a half hours into two working portions. These portions should be arranged something in this way:—

Monday to Friday, work from 7.30 to 12 o'clock; dinner from 12 to 1; work from 1 to 6; and then knock off. Saturday, work from 7.30 to 12.30 and knock off. But this makes the working hours 52½ instead of 54. Yet the five hours' work without a break allotted for Saturday cannot be increased, and the alternative would be to work to 6.30 on three nights a week. To this there are strong objections. This one and a half hours, therefore, might be conceded to the men, and it would be more than made up by the avoidance of losses which occur under the present system.

The counter proposal that the men should begin at seven o'clock might be worked out thus:—Monday to Friday, work from 7 to 12; dinner from 12 to 1; work from 1 to 6; and then knock off. Saturday, work from 7 to 11, and knock off, making 54 hours.

Of the two, the writer believes the first arrangement would come out more profitably for employers, and it would be much more popular with the men. To make knocking-off time later than six would rouse universal opposition; in fact, many among the younger men, and possibly a majority, would prefer to retain the present arrangement, and leave work at 5 or 5.30 rather than continue until 6, and so shorten the evening. On the other hand, there are objections to beginning work so early as 7, under the condition of having breakfast first. For this concerns not the workman alone, but his wife also, who at present does not usually arise with her husband, but sleeps an hour or more

longer in consequence of having the care of children, which often compels her to remain up working after he has retired to rest.

The proposed arrangement to begin work at seven would, therefore, press very hardly on many wives, who, in any case under the proposed new system, would be compelled to rise by about 6 o'clock, and in many instances by 5.30, in order to get breakfast for the good man who might have a mile or two to walk to get to his work by seven o'clock. For this reason, as well as on account of the shortening of the evening, the proposal to begin at seven would not be received so favourably by the workmen as that of 7.30, with the slight concession of the hour and a half just referred to offered.

Further, in considering this question we have to remember that the workmen are differently situated in large cities like Manchester and London from those in country towns, and the problem may ultimately be solved by adopting one arrangement for the first and another for the second. The latter class would be put to less inconvenience by beginning work at 7 than the former would at 7.30. In the country towns the men's cottages cluster in the vicinity of the works; in the great manufacturing cities they are often from two to four or five miles away. Men situated thus would hardly be relieved by starting work at seven instead of six, when coupled with the necessity of having breakfast before leaving home. Few men, moreover, would have an appetite for breakfast at so early an hour as 5.30 or 6. It is created by the first spell of work, and then five hours would be long to wait for dinner, and surreptitious luncheons would be munched. Again, in country towns people go to rest earlier than they do in large cities because there are few inducements in the shape of amusements, or lectures, or social gatherings to keep them late from home. They will, therefore, rise early more readily.

Though the writer has pointed out the nature of the difficulties that would surround the readjustment of the hours of labour, this has been done solely with a view of indicating the lines of least resistance along which the change may be accomplished. So depressing, almost brutalising, and deadening to ambition and energy is the existing system that any change, even though but of a tentative character, would be better than to go on as several generations of workmen have been compelled by force of circumstances to do. When one reads the torrents of unmitigated abuse which ignorant scribes pour out on the heads of workmen, it is sometimes to be wished that these arm-chair critics were compelled to crowd the factory gates in the gray of morning, in slush and snow, unwashed, unkempt, with boots as yet unlaced, tie in trousers pocket, buttons unfastened, crowding and jostling lest their checks should not be put in before the clock strikes six.

If British trade is to be conserved, one condition is that the life of the workman shall be brightened, his pulses quickened, his interests aroused, and one element in this is a readjustment of the hours of labour on the lines here indicated. As a mere matter of economy the present arrangement is the worst possible. But beyond and above that looms the higher question of the loyalty of workmen, the cementing of interests which should be mutual. To gain these is worth much effort. They are the best insurance against strikes and union troubles.

THE EFFICIENCY OF MARINE BOILERS

By G. M. Brown, B. A., Wh. Sch.

IN discussing improvements looking towards further increases in the efficiency of marine boilers in a paper recently presented before the North-East Coast Institution of Engineers and Shipbuilders, the author pointed out that in 1857 the late Lord Armstrong and two other gentlemen were appointed to carry out a series of experiments on the respective values of North Country and Welsh coals for marine purposes. The result of their labours was the famous Newcastle experiments. The boiler they used was one of the old, wet-bottom type, with an internal uptake, and a feed heater at the base of the chimney, which reduced the temperature of the waste gases by about 50 degrees, and steam was generated at atmospheric pressure. Under such conditions it was possible to attain a very high efficiency, as the following figures show:—

	Water Actually Evaporated Per lb. of Coal	Eaporative Power of Coal (by Calorimeter)	Efficiency Per Cent
Aberaman Welsh coal, hand-picked	12.35	14.30	86.5
Hartley coal, large and small	12.91	14.63	88.2

Shortly afterwards, similar experiments were carried out on the same boiler, by Messrs. Millar & Taplin, on the boilers of the S.S. *Isabella Croll*, by Mr. Dobson, and on the Keyham Factory Boiler. A full account of all these trials will be found in *The Steam-Engine*, by D. K. Clark, Vol. I. The general result obtained was, that a fairly rapid rate of combustion gives the best results, provided the grate area is not large. Since then other tests have been made, but still the major part of the data available to the marine engineer is very old. It is to be regretted that those who have made tests of more modern boilers have, with a few exceptions, either not taken all the necessary data to render their results of practical value, or have not thought fit to publish their results for the benefit of their fellow-workers.

The last two decades have seen an enormous change in the marine engine, but the same boiler is still in general use, neglecting a few structural changes necessitated by the greatly increased pressures lately introduced. So far the steam-engine has had every attention, and it is certain that no great increase of efficiency can be obtained by increasing the working pressure. On the other hand, the boiler, the efficiency of which is every whit as important as that of the engine, has had comparatively little attention paid to it; few people have studied its action or endeavoured to increase its efficiency. Especially is this the case with the marine boiler as now used; indeed, so far as the writer is aware, no complete measurements of the temperatures and pressures of the products of combustion as they pass from the furnace to the chimney has ever been made. It is questionable whether, with the increased steam pressures now in use, the efficiency of the ordinary marine boiler is not, in general, much less than it was formerly, for these increased pressures have necessitated the abandonment of the feed heater, at one time commonly used in marine work and fitted in the uptake

so that it abstracted heat from the chimney gases. That this is a retrograde step there can be no doubt whatever; in the writer's opinion, such a feed heater would be a much more valuable adjunct to the high-pressure boilers in present use than it was in the case of the old low-pressure boilers.

It is humiliating to engineers to think of the great waste of energy going on about them, and more especially of that waste wilfully allowed to go on because it is supposed to be necessary to create a chimney draught by allowing a large mass of highly-heated gases to pass away from the boiler and carry with it about 20 per cent. of the heat generated by the coal consumed in the furnaces. Temperatures of 700 degrees Fahr. and more are common in the uptakes of ordinary marine boilers working with natural draught and having plain tubes.

Assuming this temperature to exist at the base of a funnel 65 feet high, and taking the atmospheric temperature to be 62 degrees Fahr., we have from D. K. Clark's formula

$$w = H\left(0.146 - \frac{7.66}{T + 461}\right)$$

where w = draught in inches of water
H = height of funnel in feet
T = temperature of gases

$w = 0.52$ inch of water which is distributed as follows:—

	Inch
Resistance due to the funnel, uptakes and smoke-box	0.02
" " tubes	0.11
" " fire-box, bridge, furnace	0.06
" " fire of moderate thickness	0.31
" " inertia of column of gases	0.02
Total	0.52

Theoretically, about 11 pounds of air are required for the complete combustion of 1 pound of coal, the result being 12 pounds of mixture of carbon dioxide, steam, and nitrogen. The amount of air actually supplied to the furnaces of boilers working under natural draught is sometimes as great as two and one-half times the theoretical quantity. If we assume that 19 pounds of air are required for the combustion of 1 pound of coal, there will be practically 20 pounds of gaseous products, having an average specific heat of about 0.23. Then of the heat generated by the combustion of 1 pound of coal (average say, 14.700 BTU) $20 \times 0.23 (700-62) = 2934.8$ BTU., or about 20 per cent., are used in creating draught.

It is evident from this that the ordinary method of producing draught is a most wasteful process, especially when it is remembered that with forced or induced draught the percentage of the heat of combustion required to work the fans at a consumption of 30 pounds per square foot of grate is about 3 per cent., according to Bertin, although Messrs. John Brown & Co. assert that in some of their larger installations which have triple expansion fan-engines it is only about 1.3 per cent.

When we consider these figures it becomes evident that there will be some advantage in utilising the heat of the waste gases otherwise than to create draught, even if, as will generally be the case, we are thereby compelled to use artificial draught. Of the several methods of doing this, perhaps the most obvious is to increase the length of the passage through water as was done by Audenet. The objection to this is the great length by which the passage has to be increased to produce any appreciable saving.

In the early days of marine engineering considerable economy was effected by superheating the steam as it passed from the boiler to the engine. As boiler pressures increased, much trouble was experienced with the superheaters and in the engines, and this plan fell into disuse. It has, however, lately been renewed in steamers of the "Inch" Line, owned by Messrs Hamilton, Fraser & Co., and engined by the Central Marine Engine Works, of West Hartlepool. But with the pressures in use at present the temperature of the superheated steam is high; for instance, in the steamship *Inchkeith* the boiler pressure is 260 pounds per square inch, the temperature of the steam at the in-

let to the superheaters is about 400 degrees Fahr., the temperature of the waste gases at the smoke box is about 650 degrees, and above the superheater about 450 degrees Fahr., so that, as far as superheating alone is concerned, we are compelled to let the gases go at a fairly high temperature, although not nearly so high as that common in many boilers working under natural draught.

Another device largely adopted on old low-pressure boilers was the feed heater fixed in the base of the chimney; but owing to the pitting and corrosion which took place, these heaters, more especially as boiler pressures increased, were a great source of trouble and danger, and their use was, accordingly, dispensed with. The late Mr. Ebenezer Kemp, of Glasgow, however, persevered with them. In several boilers for the Clan Line he used small coils by means of which the feed water was raised about 40 degrees in temperature and the waste gases were reduced in temperature; but his first serious work in this direction seems to have been done on the S.S. *Bléville*, into which he fitted heaters having a collective heating surface about double that of the boilers, and also an exhaust fan at the base of the funnel. He succeeded in reducing the temperature of the waste gases from 1040 degrees Fahr. to 356 degrees Fahr, and in raising that of the feed water from 120 degrees Fahr. to 360 degrees Fahr. The hot gases were thus discharged at a temperature of 236 degrees Fahr. above that of the incoming feed water. The usual troubles through corrosion and pitting of the tubes soon led to the abandonment of this plan.

In the S.S. *Caloric* Mr. Kemp adopted the closed ashpit system of forced draught, and as feed heaters used four small cylindrical boilers. In this case the gases left the smoke box at 680 degrees Fahr., and after passing through the feed heaters had a temperature of 236 degrees Fahr. The temperature of the water was raised about 36 degrees Fahr. in each feed heater, *i. e.*, 144 degrees Fahr. in all. In this case also there was some trouble through the corrosion of the tubes near the feed water inlet. Soon after Mr. Kemp retired from practice, and his idea seems to have been abandoned, but has been recently revived in the Navy, H.M.S. *Diadem* having a feed heater above each of its Belleville boilers.

Perhaps the most satisfactory method of utilising the heat of the waste gases is that adoped by Mr. Howden in his closed ashpit system of forced draught, and Messrs. Ellis and Eaves in their system of induced draught, that is, to heat the air necessary for combustion.

Another method of abstracting heat from the products of combustion is to increase the heat-absorbing surface of the boiler. In 1840 Mr. C. W. Williams patented the application of "conductor pins" to heating surfaces. The pins were fixed perpendicularly to the heating surface so that the hot gases impinged directly on them. The superior efficiency of a heating surface fitted with these pins was clearly demonstrated in the following manner:— Into three tin boilers, each with an internal flue, 22 pounds of water at 58 degrees Fahr. were measured, and then the products of combustion of 30 cubic feet of gas were passed through each in turn, the gas in each case being consumed in 2 hours 40 minutes, with the following results:—

No. 1.	Plain	evaporated 4.25 lbs.	of water
No. 2.	With conductors on outside only	" 7.90	"
No. 3.	" " inside and outside	" 8.31	"

The temperatures of the escaping gases were 406 degrees Fahr., 320 degrees Fahr., and 284 degrees Fahr., respectively. A later development of this principle is seen in the Serve tubes, to which Messrs. Ellis & Eaves largely attribute their undoubted success. By means of the internal ribs in these tubes the heat absorbing surface is increased by 75 per cent. more than that of a plain tube of the same dimensions. In consequence of this, it is stated by the makers that when a boiler is fitted with 3¼-inch Serve tubes, 7 feet long, the

temperature of the gases in the smoke box is the same when the ratio of heating surface (calculated in the ordinary way) to grate surface is 28 to 1 as with 40 to 1 and plain tubes, a difference of about 43 per cent. in favour of the Serve

FIG. 1.—A SERVE BOILER TUBE

tube. The experiments of the late Mr. Blechynden show the Serve tube to be 33 per cent. more efficient than the plain tube.

Messrs. J. Brown & Co. use with the Serve tube spiral retarders for the purpose of breaking up the column of gas passing through each tube and bringing it into intimate contact with the heating surface, as also does Mr. Howden. The effect of introducing a spiral retarder into a boiler tube is to compel the gaseous products of combustion to follow a very tortuous course, and if there is not a very strong draught

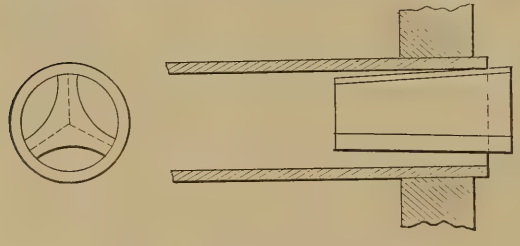


FIG. 2.—A HAWKS RETARDER

through all the tubes, solid matter, such as fine ash and unconsumed carbon, is deposited in the tubes, with the result that the lower rows rapidly become stopped up and useless, and a large portion of the heating surface is thrown out of action, and the power and efficiency of the boiler are diminished.

It is a well-known fact that in all return tube marine boilers the lower rows of tubes rapidly become stopped up, the reason being that the draught through them is very sluggish. The hot products of combustion pass over the bridge with a velocity of about 450 feet per minute and impinge on the back of the combustion chamber, where they spread outward and upward. The main part flows up the back of the combustion chamber round the top and into the upper rows of tubes, the rest passing up the sides and out of the upper side rows of tubes. The cooler and unconsumed portions follow a shorter path, and are drawn into the lower rows of tubes where their combustion becomes impossible. It is evident that if the hot gases are compelled to take a longer path and are more thoroughly mixed together before entering the tubes, as they must do if the upper rows are wholly or partially plugged up, combustion will be rendered more perfect. Moreover, the greater the evaporation from the lower rows of tubes, the better will be the circulation of the water in the boiler, and hence, for a double reason, we may expect the efficiency of a boiler to be increased by properly regulating the amounts of the hot gases passing through the various tubes. That this reasoning is true is borne out by the fact that in many steamers using spiral retarders they are removed from the lower rows of tubes and the performances of the boilers are thereby improved.

Isherwood, in 1864 conducted a series of experiments on a small, new and clean marine boiler, to test the influence of various arrangements and proportions of heating surfaces, and of various rates of combustion. The boiler was rectangular in shape with a semicircular top, and was 3 feet 1½ inches wide by 6 feet 7 inches long by 6 feet 5 inches high, with one furnace 26 inches diameter and twenty four tubes, 3 inches external diameter and 5 feet 10½ inches long, arranged in four rows of six each. With this the following results were obtained:—

First Series:—Varying heating surface of tubes and tube section by plugging up rows of tubes at both ends. Grate area 10.89 square feet. Combustion about 16.5 pounds per square foot per hour.

State of Tubes	Heating Surface	Surface Ratio	Tube Sections	Water per lb. of Coal from and at 212°
	Sq. Ft.		Sq.Ft.	
Normal	150.3	14	.99	6.78
Lowest row plugged	125.1	11.58	.64	6.33
3 rows "	99 9	9.25	.495	7.00
2 " "	74.72	6.92	.25	6.71

Second Series:—Tube surface as above. Rate of combustion proportional to heating surface.

State of Tubes	Lbs. Coal per 48 Hours	Lbs. Coal per Square Foot of Grate	Coal per Square Foot of Heating Surface	Water per lb. of Coal from and at 212°
Normal	8,591	16.37	.969	6.78
Lowest row plugged	7,127	13.75	.993	7.04
3 rows "	5,720	11.03	1.009	7.57
2 " "	3,876	7.48	.912	9.28

Third Series:—Constant grate area, heating surface, and rate of combustion. Tube section varied by inserting ferrules in both ends of all tubes.

Ferrules ½ in. Long	Tube Section	Lbs Coal per 48 Hours.	Lbs. Coal per Square Foot of Grate	Water per lb. of Coal from and at 212°
	Sq. Ft.			
	.99	8,591	16.57	6.78
3-16 ins. thick	.738	8,659	16.53	6.85
7-16 "	.460	8,617	16.61	6.85
¾ "	.204	2,94	5.79	8.59

In 1863 he conducted experiments on the effect of plugging up tubes in a marine boiler, 12 feet long, 7½ feet wide, and 12 feet high, with two furnaces 3 feet wide, and 144 tubes, 3 inches external diameter, and 8 feet 3 inches long, there being nine rows of eight tubes to each furnace. The combustion chambers were not large. The first series of trials was made with the boiler (1) in its normal state, (2) with two upper rows, (3) with three upper rows, (4) with four upper rows of tubes successively plugged up at both ends, with the results given in Table I., on the next page.

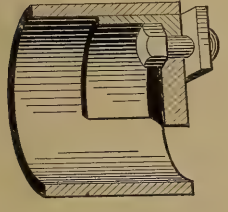


FIG 3.—A SCOTT RETARDER

The second and third series were made with a different coal. In the second set the boiler was (1) in its normal state, (2) with two lower rows, (3) with three lower rows, (4) with four lower rows of tubes successively plugged at both ends. Table II. gives the results for this series.

In the third series the boiler was (1) in its normal state, (2) with two inner vertical rows, (3) three inner vertical rows, and (4) four inner vertical rows of tubes plugged at both ends, the results being given in Table III.

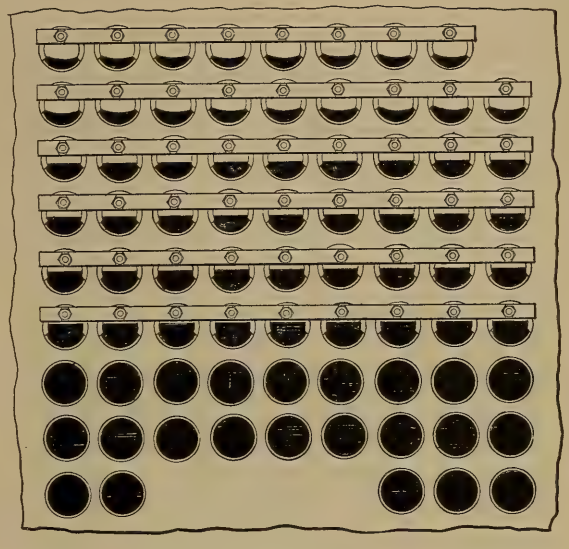


FIG. 4.—SCOTT RETARDERS BOLTED TOGETHER IN ROWS

Similar experiments were carried out by Mr. Isherwood on the boilers of the U. S. steamer *San Jacinto*, with analogous results.

It has been stated that the results of the above experiments show the tube surface to be practically useless so far as steam raising is concerned, but what is more probable is that the reduction of tube section entails the admission of less air per pound of coal burned and more perfect combustion, especially with the upper rows of tubes plugged up, as well as a higher velocity of the gases over the surface of the tubes, a condition known to be favourable to their efficiency.

The one thing these figures do point out is the desirability of using small tubes in boilers and thus obtaining a large amount of heating surface, small tube section, and high velocity of the gases through the tubes, the latter con-

RESULTS OF TRIALS TO DETERMINE THE EFFECT OF PLUGGING UP TUBES IN A BOILER

TABLE I.

	1	2	3	4
Coal per square foot of grate per hour, lbs.	11.6	13.3	9.8	10.5
Water, per lb of coal from and at 212°, lbs.	8.4	8.9	9.8	9.9
Temperature in uptake	469°	453°	541°	616°

TABLE II.

	1	2	3	4
Coal per square foot of grate per hour, lbs.	13.9	12.4	13.1	12.0
Water, per lb. of coal from and at 212°, lbs.	9 3	8.3	9.1	9.6
Temperature in uptake	460°	453°	575°	603°

TABLE III.

	1	2	3	4
Coal per square foot of grate per hour, lbs.	11.6	12.4	13.2	12.8
Water from and at 212°, per lb. of coal, lbs.	9.3	8.3	9.4	9.3
Temperature in uptake	460°	478°	568°	597°

dition being the most important; but, unfortunately, for practical reasons this is not feasible, and marine engineers are compelled to use large tubes. Whether the large tubes are Serve tubes or not, experience has shown the desirability of reducing the area for the passage of the hot products of combustion preferably by means of some form of retarder. Several forms of retarder are in use. One of the first to be introduced was that of Mr. N. Hawks. These are merely metal plugs of the shape shown in Fig. 2, and are made with a fair taper to meet slight inequalities in the sizes of the tubes.

Spiral retarders are well known and require no description. In many cases a great saving of fuel has been brought about by their use, but they are somewhat clumsy to handle in the stokehold. One advantage they have is that the tubes may sometimes be partiallly cleared by working them in and out.

Mr. John Scott has recently introduced a form of retarder (Fig. 3) which has several advantages, the chief being that the area left in each row of tubes for the passage of the products of combustion may be regulated so as to secure the best results. Being bolted together in rows, as shown in Fig. 4, they are easily and expeditiously removed from the tubes when necessary, and occupy less space in the stokehold. From the fact that the flow of the products of combustion through the various tubes is regulated, we might expect these retarders to be, if anything, more efficient than the spiral retarders, even though they do not bring the hot gases into such close contact with the tube surface. Table IV. gives the results of three tests carried out on a boiler 10 feet 6 inches in diameter and 10 feet 6 inches long, with two Purvis flues 2 feet 10½ inches in diameter, and 116 3¼-inch Serve tubes, 7 feet 6 inches long, with no retarders, with spirals, and with Scott's retarders. The boiler was worked under Messrs. Ellis & Eaves' system of induced draught.

These are the only figures relating to systematic tests on retarders the writer has been able to obtain.

Table V. contains the main results of ten voyages made by a steamer running in the cross Channel trade before and after fitting retarders. The ship has two single-ended boilers each with three furnaces, and one single-ended boiler with two furnaces, all having tubes 3¼ inches in diameter, and working under natural draught. The data given are thoroughly reliable, as the coals were accurately weighed.

The figures in the first column are the averages for the best ten voyages in the two and one-half years preceding the fitting of the economisers, and in the second column for the ten consecutive voyages after the retarders were fitted; they show a saving of 9.7 per cent. in coal, and 1 per cent. in time in favour of the retarders.

With regard to ships making longer voyages, the figures in Table VI. are abstracted from the engineers' logs for three voyages of a ship, No. 1 before the vessel was fitted with retarders, and

TABLE IV.

	No Retarders	Spiral Retarders	Scott's Retarders
Length of trial	6 hours	6 hours	6 hours
Coal burned in lbs.	8,960	8,960	8,960
Water evaporated, lbs.	67,000	76,900	77,600
Temperature of feed water	52.9	58.6	57.5
Steam pressure in lbs	47	46	47
Temperature of air at side valve	332.9	312 2	342.7
Temperature of gases at base of chimney	470.4	422 2	465.9
Temperature of gases in smoke-box	melted lead	just melted lead	melted bismuth
Vacuum at base of chimney, inches of water	3.93	4.26	4
Vacuum at fan outlet, inches of water	.25	.35	.375
Speed of air under grate bars, feet per minute	2,645	3,000	2418.1
Speed of air through heating tubes, feet per minute	1277.7	1,318	1090.9
Lbs of water per lb. of coal from and at 212°	8.89	10.16	10.27

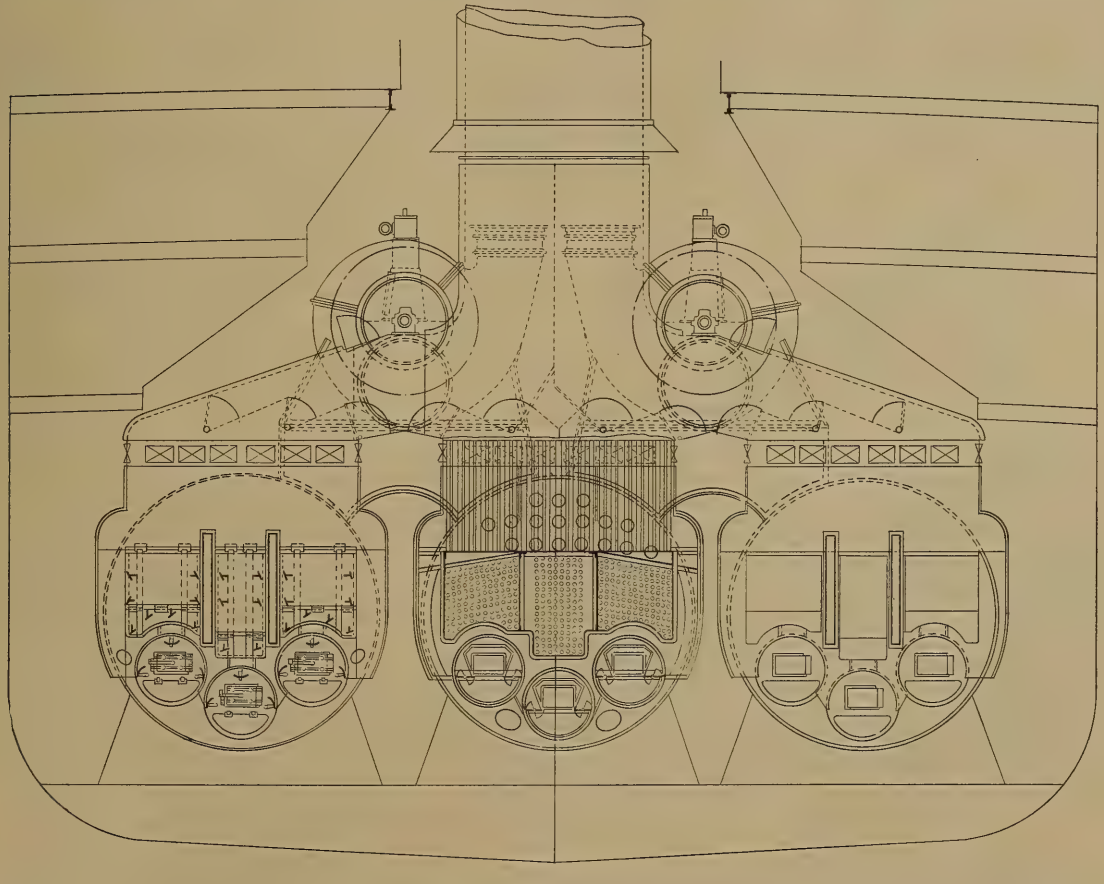
Nos. 2 and 3 after fitting with Scott's retarders.

The writer has been unable to collect data bearing on the performance of other types of plugs and retarders. It is only in Mr. John Scott's system that any attempt is made to regulate the distribution of the products of combustion; in other types the same retarder is put into all the tubes, except, perhaps, the two bottom rows. The greatest saving is effected in fitting retarders into boilers with large tube section, and, to derive the utmost benefit from their use, the combustion chambers should be roomy; and hence any brickwork at the backs of the chambers should be removed. Indeed, roomy combustion chambers are essential to the efficiency of a boiler, whether retarders are put in the tubes or not.

TABLE V.

	Without Retarders	With Scott's Retarders
Consumption of coal per voyage, tons	29.9	27
Average revolutions per minute	70.5	69.2
Time on passage	12 hrs. 20 mins.	12 hrs. 12½ mins

The above figures show very clearly



THE ELLIS & EAVES INDUCED DRAUGHT SYSTEM AS INSTALLED BY MESSRS. JOHN BROWN & CO., LTD., SHEFFIELD, ENGLAND

TABLE VI.

Voyage	Total Full Speed Steaming Time		Average Daily Consumption		Average Speed	Knots per Ton of Coal	Total Cost Used for Main Engines
	Days	Hours	Tons	Cwts.	Knots		
No. 1	14	18	21	18	9	9.7	977
No. 2	46	1	19	0	9.3	11.6	877
No. 3	45	1	17	14	8.8	11.7	803

COMPARISON OF VOYAGES NOS 2 AND 3 WITH VOYAGE NO. 1

	Daily Coal Consumption Reduced	Average Speed Increased
	PerCent	Per Cent
No. 1		
No. 2	13.3	3.3
No. 3	19.2	2.3

the benefits to be derived from the use of a proper outfit of retarders.

Lately Messrs. J. Brown & Co., working in conjunction with the Central Marine Engine Works, have made a notable advance in using the waste gases, not only to heat the air supplied to the furnaces, but also to superheat the steam generated in the boilers. This system is applied on the steamships *Inchkeith*, *Inchmarlo*, and others, and an idea of the increased efficiency of this system, compared with the primitive natural draught, can be formed when it is stated that in the *Inchkeith* the chimney gases have a temperature of 380 degrees Fahr. only,* and the *Inchmarlo*, which is fitted with the Central Marine five-crank engines, on a recent trip from Hartlepool to Dover burned only 0.97 lb. of coal per I. H. P. per hour. It is open to question whether a further saving might be effected by passing the waste gases through a feed heater, and reducing their temperature still further. Compared with the 236 degrees Fahr. attained by Mr. Kemp, 380 degrees Fahr. is still a high temperature at which to allow them to escape, and by passing them through a feed heater, as suggested, it might be possible to make a further saving of about 3 or 4 per cent.

* In making a comparison of chimney temperatures under natural and forced draughts, it is well to remember that a much smaller quantity of air is generally required per lb. of coal with the latter than with the former, especially with a heated air supply

LOCOMOTIVE BUILDING IN THE UNITED STATES

By John H. Converse, President of the Baldwin Locomotive Works

FIG. 1.—PETER COOPER'S LOCOMOTIVE,—THE FIRST ONE BUILT IN AMERICA

IT is generally conceded that the first locomotive built in America was constructed by Mr. Peter Cooper, of New York City. It was placed on the Baltimore & Ohio Railroad in 1829, and was designed to demonstrate the practicability of using steam locomotives on the railroad track of that company which then extended only thirteen miles, to Ellicott's Mills, Md. The question had been raised as to the practicability of a locomotive working around the short curves which existed at various points along the line, but the test of the engine settled this question.

The second locomotive built in America was undoubtedly *The Best Friend*, built in 1830 by the West Point Foundry Company, of New York City, for the South Carolina Railroad. Two other locomotives were built in that and the following year by the same establishment. Colonel Stephen H. Long, of the United States Army, associated himself in 1830 with Mr. Norris, of Philadelphia, and in 1831 began the construction of a locomotive which was tried on July 4, 1832, on the Newcastle & Frenchtown Railroad.

In the same year Mr. Matthias W. Baldwin, of Philadelphia, contracted to build for the Germantown Railroad a small locomotive, which was finished in November, 1832, and was called the *Old Ironsides*. This practically formed the foundation of the now famous Baldwin Locomotive Works. At about the same time the firm of Davis & Gartner, of York, Pa., constructed their first locomotive, the *Atlantic*. Mr. William T. James, of New York, also made one or two locomotives at about this period.

The business having thus been established, a considerable number of firms

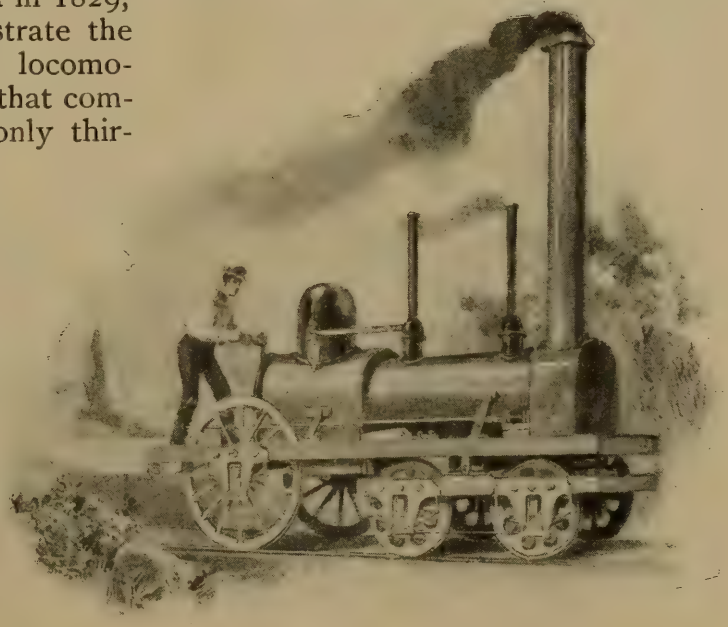


FIG. 2.—AN ENGINE OF 1833 WITH SWIVELING FOUR-WHEELED TRUCK

or corporations undertook the manufacture of locomotives. New England led in this respect, and it is interesting to note the names of some of the concerns which had to do with locomotive manufacture in the first half of the nineteenth century. At Taunton, Mass., there were Mr. William Mason and the Taunton Manufacturing Company; at Boston, the Boston Locomotive Works, Messrs. Hinckley & Drury, Mr. Seth Wilmarth, Mr. John Souther, whose establishment was called the Globe Works; Messrs. McKay & Aldus, and Mr. Jabez Coney. At Manchester, N. H., there were two works, the Amoskeag Manufacturing Company and the Manchester Locomotive Works. The latter is still in business. There were also works at Springfield and Lawrence, Mass., and the Ballardvale Works at Andover. At Lowell the Locks & Canal Company began the building of locomotives in 1834. Their works were afterwards known as the Lowell Machine Shop. In Maine the Portland Locomotive & Car Works were engaged in the building of locomotives until about 1870. At Providence, R. I., Messrs. Corliss & Nightingale for a time made locomotives, and also the Rhode Island Locomotive Works, which were established in 1865 and are still engaged in business. In New York and New Jersey there were works at Trenton managed by Messrs. Van Cleve, McKean, Dripps & Co ; at Jersey City there were the Jersey City Locomotive Works, Messrs.

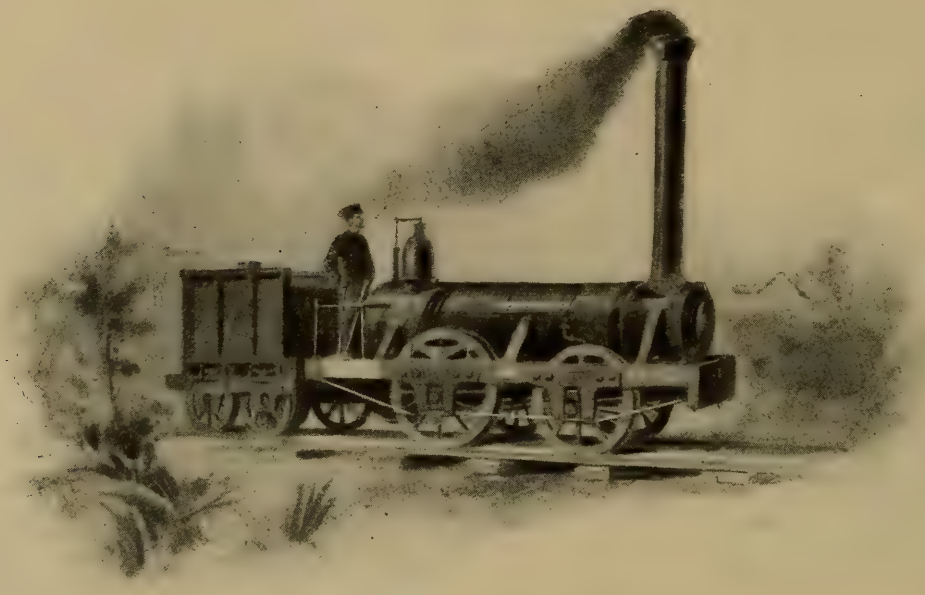


FIG. 3.—THE "OLD IRONSIDES," 1832

Breece, Neeland & Co., and the New Jersey Locomotive Works of John Brandt; at Paterson were the Rogers Works, founded by Messrs. Rogers, Ketchem & Grosvenor in 1837, the Danforth & Cooke Works, and the Grant Locomotive Works, which went out of business about 1875, and were subsequently conducted in Chicago under the same name for one or two years. There were also Messrs. Swinburne & Smith, and the Mattewan Works. Mr. Edward Norris established a locomotive works at Schenectady in 1848, which subsequently became the Schenectady Locomotive Works, incorporated in 1851. There were also the Brooks Locomotive Works, at Dunkirk, N. Y., founded in 1869, and later the Rome Locomotive Works, at Rome, N Y. In Ohio there were works at Zanesville, at Cleveland the Cuyahoga Works, and at Cincinnati the shops of Messrs. Moore & Richardson and Niles & Co. In Pennsylvania there were the works of the Lancaster Locomotive Works, the Norris Locomotive Works, the Dickson Locomotive Works at

Scranton, the Pittsburgh Locomotive Works and Messrs. H. K. Porter & Co. at Pittsburgh, and Messrs. Eastwick & Harrison and the Baldwin Locomotive Works at Philadelphia. In addition to these locomotives were built by Messrs. Smith & Perkins at Alexandria, Va., by Messrs. Ross, Winans & Denmead at Baltimore, and the New Castle Manufacturing Company at New Castle, Del. The Richmond Locomotive Works, which have been developed at Richmond of late years, are now the only locomotive building establishment in the South. The works at present in business in the construction of ordinary railroad locomotives are the following:—

Baldwin Locomotive Works, Philadelphia, Pa.
Brooks Locomotive Works, Dunkirk, N. Y.
Cooke Locomotive & Machine Works, Paterson, N. J.
Dickson Locomotive Works, Scranton, Pa.
Manchester Locomotive Works, Manchester, N. H.
Pittsburgh Locomotive & Car Works, Pittsburgh, Pa.
H. K. Porter Co., Pittsburgh, Pa
International Power Co., Providence, R. I.
Schenectady Locomotive Works, Schenectady, N. Y.
Richmond Locomotive Works, Richmond, Va.
Lima Locomotive & Machine Works, Lima, Ohio.

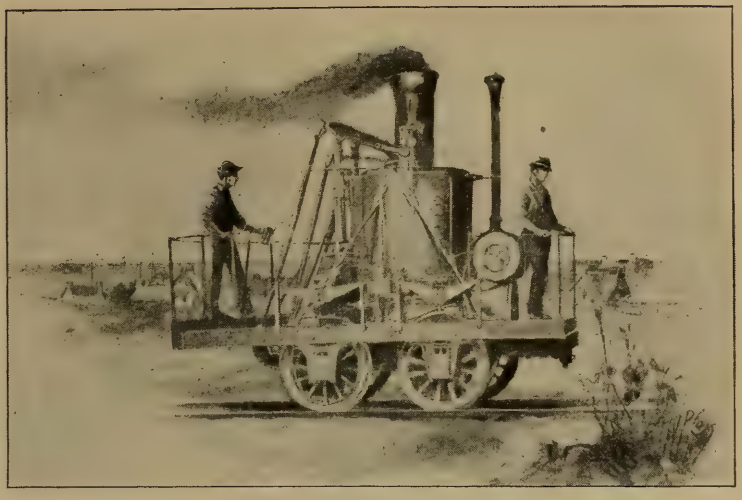


FIG. 5.—A BALTIMORE & OHIO "CRAB," 1832

An excellent means of tracing the development of the locomotive in the United States is afforded in the illustrations accompanying this article, exemplifying some of the latest practice of different American establishments, and representing, too, noteworthy periods in the earlier locomotive history of the country. The *Old Ironsides* shown in Fig. 3 was the first locomotive built at the Baldwin Works, in 1832, for the Philadelphia, Germantown & Norristown Railroad. It had a single pair of driving wheels and a single pair of leading wheels, and weighed, in working order, about five tons. Figs. 4 and 5 represent, respectively, a double-bogie locomotive built in 1832 for use on heavy inclines on the South Carolina Railroad, and one of the locomotives styled "crabs," built for the Baltimore & Ohio Railroad in the same year.

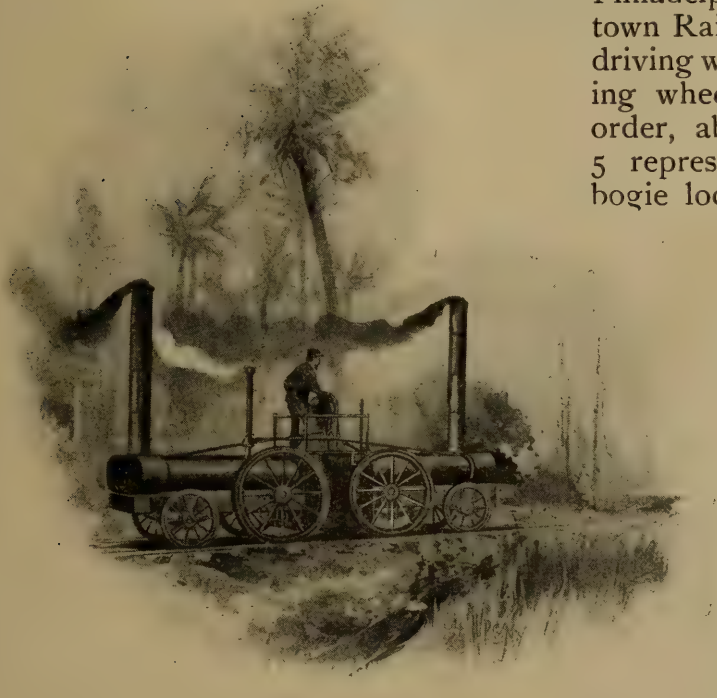


FIG. 4.—DOUBLE-BOGIE LOCOMOTIVE ON THE SOUTH CAROLINA RAILROAD, 1832

Fig. 2 represents a type of locomotive introduced in 1833, in which also a single pair of driving wheels was used, but the rigid leading wheels of the *Old Ironsides* were replaced by a swiveling four-wheeled truck,—an arrangement which afforded greater flexibility and obviated the liability of derail-

ment in passing curves. This was the leading type in American locomotive practice for a number of years.

Fig. 6 shows the next step in the development,—a locomotive having two pairs of coupled driving wheels with a four-wheeled swiveling truck, invented by H. R. Campbell in 1836. This type of locomotive is in general use at the present time; and although improvements have been made in the details of construction, and weight and hauling capacity have been enormously increased, the design still remains, and is properly called the "American" type.

Fig. 7 shows a locomotive equipped with the Baldwin flexible beam truck, invented by M. W. Baldwin in 1842. With this construction the whole weight of the locomotive was utilised for tractive effort, all the wheels being coupled. The two forward pairs, however, were combined in a flexible frame secured to the main rigid frame of the locomotive by ball and socket joints. The two sides of the frame of this truck were independent of each other, and the point of support to the main frame was on a line midway between the wheels, thus allowing each frame a certain amount of lateral swing. All the wheels were flanged, and the flexibility obtained by the truck allowed the locomotive to pass curves of short radius without difficulty. This design was used both for six and eight-coupled locomotives, and for many years was a leading type for freight service.

Fig. 8 represents a locomotive of the ten-wheel type, having three pairs of coupled wheels and a four-wheeled leading truck. This type was invented by Septimus Norris in 1846, and, with improvements in detail, is used at the present time for fast freight and heavy passenger service. Fig. 10 represents a locomotive of the Mogul type, having three pairs of coupled wheels and a two-wheeled leading truck built by the Baldwin Locomotive Works in 1867 for the Thomas Iron Company. The first locomotive of this type was built in 1861 at these works, and was similar in construction to the ten-wheeled type, but with the rear truck wheel omitted. This design left considerable distance between the forward driving wheel and the truck, and it was found that the weight could be much more satisfactorily distributed by rearranging the driving wheels and closing up this space Locomotives of the same general design as that shown in Fig. 7 are at present largely used in freight service.

Fig. 9 shows the first locomotive of the consolidation type, having four pairs of coupled wheels and a two-wheeled leading truck. This locomotive was

FIG. 6.—CAMPBELL'S ENGINE, 1836

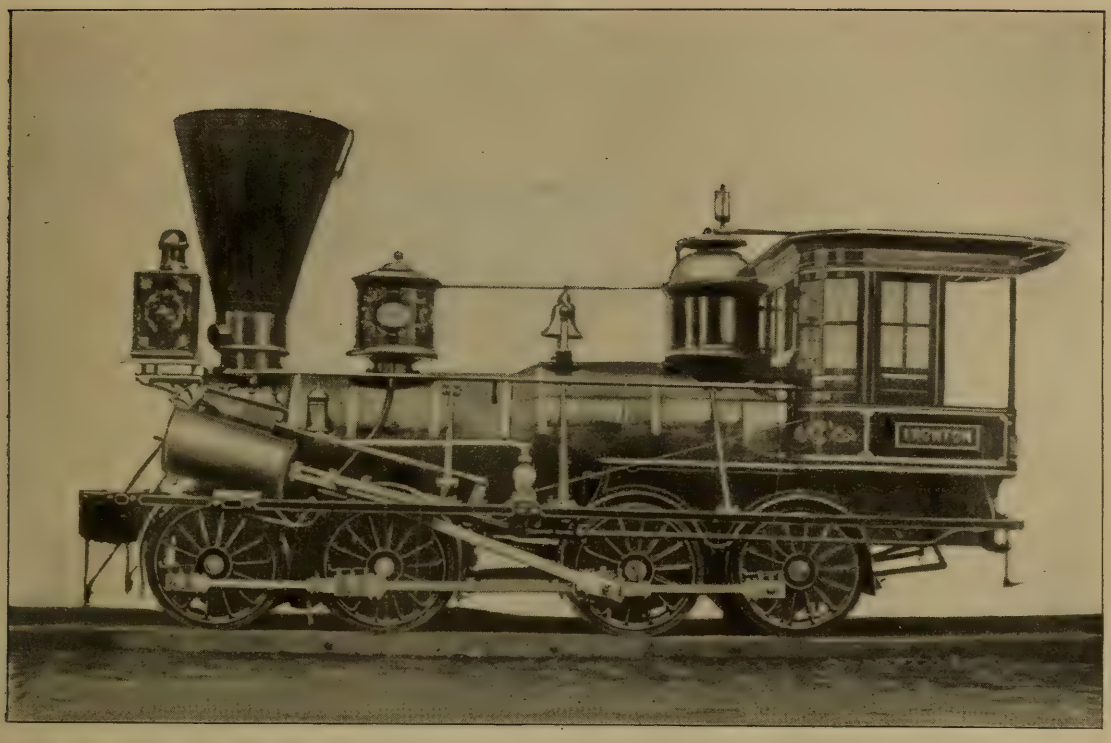


FIG. 7 —BALDWIN'S ENGINE, 1842

built by the Baldwin Locomotive Works in 1866 from a general design suggested by Alexander Mitchell, superintendent of motive power of the Lehigh Valley Railroad, and since that time has been extensively used in heavy freight service.

Fig. 11 illustrates a modern form of the American type locomotive. It will be seen that the principal features, as far as the arrangement of the wheel base is concerned, compare with the Campbell locomotive of 1836, shown in Fig. 6; otherwise, however, the similarity is lost. This locomotive was built by the Baldwin Locomotive Works for the Baltimore & Ohio Southwestern Railroad, and is used in passenger service.

Fig. 13 shows a modern ten-wheeled locomotive of the Vauclain four-cylinder compound system, built by the Baldwin Works for the Chicago, Milwaukee & St. Paul Railway, and used in passenger service. Fig. 14 represents a modern Baldwin locomotive of the consolidation type. This engine has cylinders of the Vauclain four-cylinder compound system, and is provided with the Wootten type of firebox for burning the smaller sizes or inferior grades of anthracite coal. This locomotive is the largest built at the Baldwin Works up to the present time. The total weight of the engine, not including the tender, is 225,000 pounds; the tender has a capacity of 7000 gallons of water, and weighs about 120,000 pounds. The locomotive is used in heavy freight service on the mountain grades of the Lehigh Valley Railroad near Wilkesbarre.

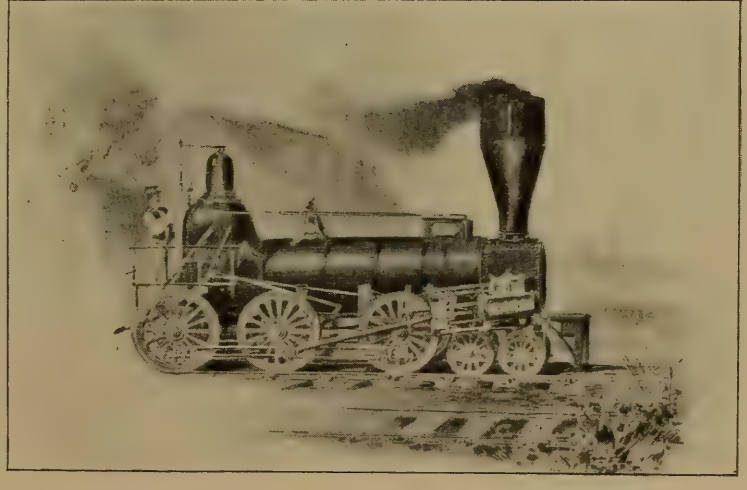


FIG. 8.—THE NORRIS LOCOMOTIVE, 1846

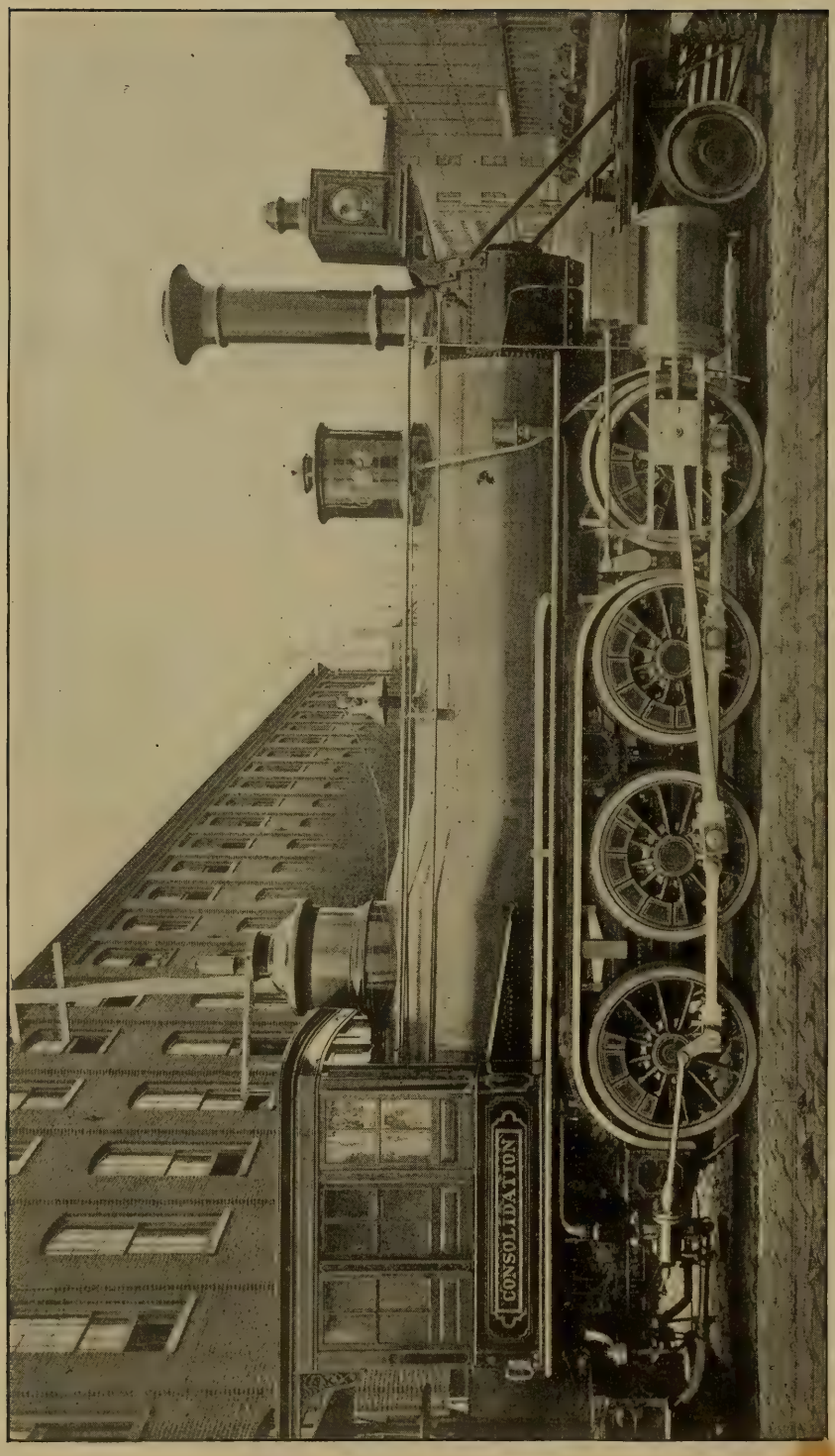


FIG. 9.—THE FIRST AMERICAN FREIGHT ENGINE OF THE "CONSOLIDATION" TYPE. BUILT IN 1866 POR THE LEHIGH VALLEY RAILROAD BY THE BALDWIN LOCOMOTIVE WORKS, PHILADELPHIA

Fig. 15 illustrates a locomotive of the "Decapod" type, having five pairs of coupled wheels and a two-wheeled leading truck, built for the Minneapolis, St. Paul & Sault Ste. Marie Railway. The first locomotive of this type was built by the Baldwin Locomotive Works in 1885 for the Dom Pedro Railway, of Brazil. The principal advantage of the design over the consolidation is that the additional pair of driving wheels, as compared with a Consolidation engine, gives two more bearing points on the rail, so that, with an equal amount of adhesion and tractive power, the weight on each axle will be less and the locomotive can be used on lighter rails.

Fig. 16 represents a locomotive of the Atlantic type, having two pairs of coupled wheels, a four-wheeled leading truck and a single pair of trailing wheels supporting the overhanging firebox. This locomotive was built by the Baldwin Works for the Chicago, Burlington & Quincy Railroad, and is equipped with the Vauclain system of compound cylinders, has driving wheels 7 feet in diameter, and is used in passenger service. The first locomotive of this type was built by the Baldwin Works in 1895 and was designed specially for high-speed passenger service. A large number have since been placed in service, and have proved remarkably successful. Examples of this type, on the Philadelphia & Reading Railway, hold the world's record for sustained speed. A number of modern designs of locomotives by different builders are shown in the other illustrations accompanying this article; but the engravings practically speak for themselves.

The foreign trade in locomotives has been a growth of the last forty years. At first it was confined chiefly to Cuba and South America. Of late years, and chiefly within the past twenty-five years, it has extended to the Eastern Hemisphere, and the growth has been very great in that direction within the past ten years, so that now American locomotives have been sent to a greater or less extent to almost every country in the world where railroads are in operation. Within the past three years American locomotives have been supplied to railways in Great Britain and France and Southern Germany. These countries have been large locomotive producers in the past, and have been competitors for foreign trade in South America, so that it is rather a remark-

FIG. 10.—A LOCOMOTIVE OF THE MOGUL TYPE. BUILT BY THE BALDWIN LOCOMOTIVE WORKS, OF PHILADELPHIA, 1867

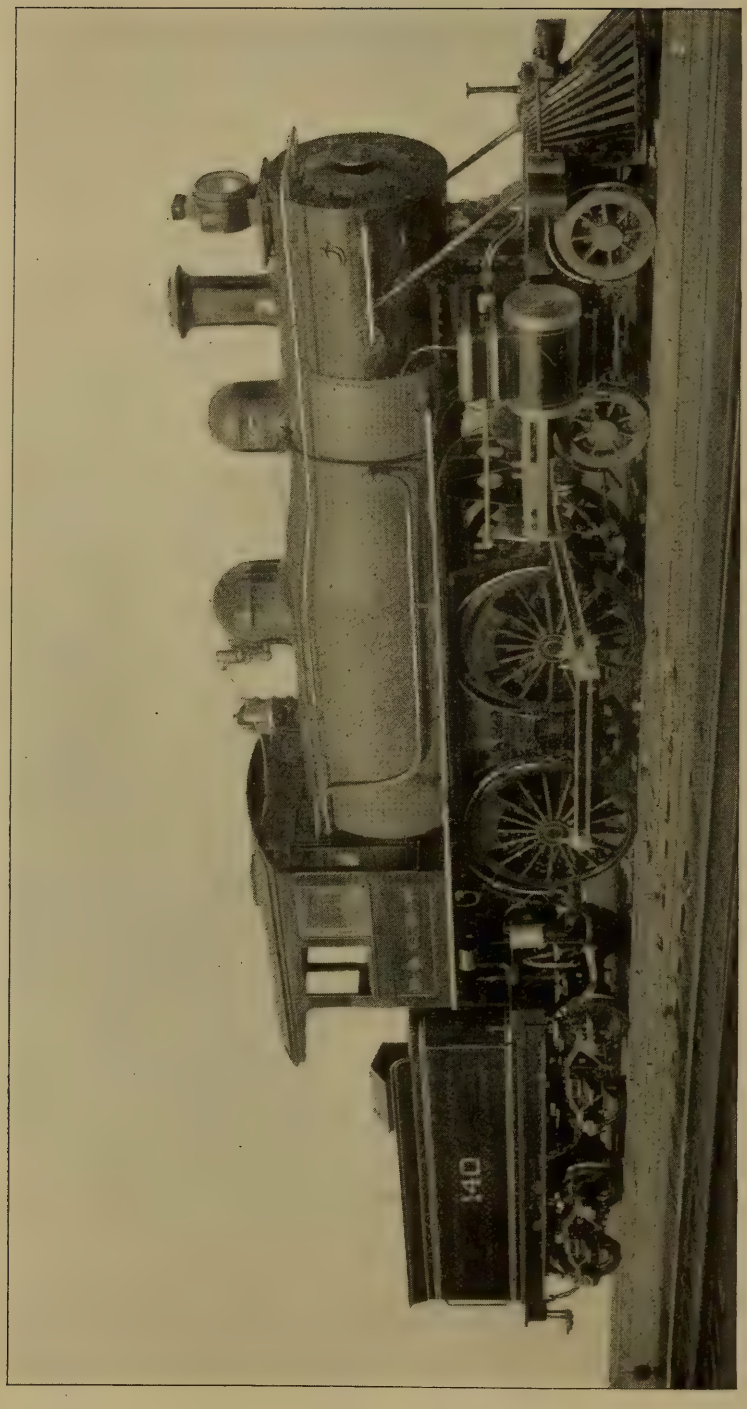


FIG. 11.—A MODERN "AMERICAN" TYPE BALDWIN LOCOMOTIVE

able development of industrial conditions in the United States that has made it possible to place American engines in those countries.

There have been three reasons for the introduction of American locomotives into Europe,—first, the possibility of much earlier deliveries than European works could make; second, to some extent the preference for American locomotives as to their type, and size, and details; and third, the question of price. Owing to the design and character of American locomotives, they can be, and have been, constructed at a less cost per unit of weight than the ordinary European locomotives, although the wages paid in America are considerably higher than the wages in European locomotive works. This may be accounted for by both the characteristics of the American workman and by the probably more extended use of labour-saving machinery of all kinds in American shops.

FIG. 12.—WIDE FIRE BOX ENGINE WITH PISTON VALVES. BUILT BY THE BROOKS LOCOMOTIVE WORKS, DUNKIRK, N. Y.

At the beginning of railroad operations in the United States the locomotive was a machine with a single pair of driving wheels, and the aggregate weight was probably not over from twelve to sixteen tons. The first change was the addition of the second pair of driving wheels and the coupling of them together, and the equalisation, as we call it, of the driving wheels, which was an American device. Then the next change was in coupling six and eight driving wheels together, and the increase in the weight of locomotives from twenty to fifty tons. That change occurred from about 1840 to 1850. In the next two decades, from 1850 to 1870, nearly all the existing types of locomotives were brought out, and there was some increase in weight. About 1870 the standard American locomotives were about forty tons in weight for an ordinary freight locomotive and about thirty-five tons for the passenger locomotive. The development has been very great within the past decade, and now freight locomotives of one hundred tons and passenger locomotives from seventy to eighty tons are the rule. All these weights are for the locomotive proper and exclusive of the weight of the tender. The weight of the tender has proportionately increased, so that, while forty years ago a 2000-gallon tender was considered to be a very liberal size, we have before us to-day for construction tenders of 7500 gallons capacity.

The increase in speed has been one of the most remarkable developments of recent years. Some can remember when the technical papers gravely dis-

FIG. 13.—A MODERN COMPOUND BALDWIN PASSENGER LOCOMOTIVE

FIG. 14.—THE LARGEST BALDWIN LOCOMOTIVE BUILT UP TO THE PRESENT TIME. TOTAL WEIGHT OF ENGINE, NOT INCLUDING TENDER, 225,000 POUNDS

FIG. 15.—A "DECAPOD" BALDWIN ENGINE

FIG. 16 —A BALDWIN COMPOUND PASSENGER ENGINE. LOCOMOTIVES OF THIS TYPE ON THE PHILADELPHIA & READING R. R. HOLD THE WORLD'S RECORD FOR SUSTAINED SPEED

cussed the question whether the speed of a mile a minute had really ever been made on any American railroad, and there were those who maintained that such a story was only a myth. To-day there are trains running in the United States scheduled at a rate which means a speed of anywhere from seventy to eighty miles an hour. They actually run on that schedule, and they do it every day. Some of the fastest time in the world is made between Philadelphia and Atlantic City. The Pennsylvania Railroad and the Reading Railroad both have their lines from Philadelphia to Atlantic City, and they have summer trains which are scheduled to make the distance from Philadelphia to Atlantic City in sixty minutes. The distance is from fifty-five to fifty-nine miles, and out of the sixty minutes they have to take the ferry from Philadelphia to Camden, so that it is on record that passenger trains are run every day in the summer season from Camden to Atlantic City, a distance of fifty-five to fifty-nine miles, in from forty-five to fifty minutes.

There has been a close relation between the development of the locomotive and the introduction of steel rails of increasing weight, and also iron and steel bridges. All those elements of the problem have been found together.

FIG. 17.—CONSOLIDATION ENGINE FOR FREIGHT TRAFFIC ON THE COLORADO & SOUTHERN RAILROAD. BUILT BY THE INTERNATIONAL POWER CO. (RHODE ISLAND LOCOMOTIVE WORKS), PROVIDENCE, R. I.

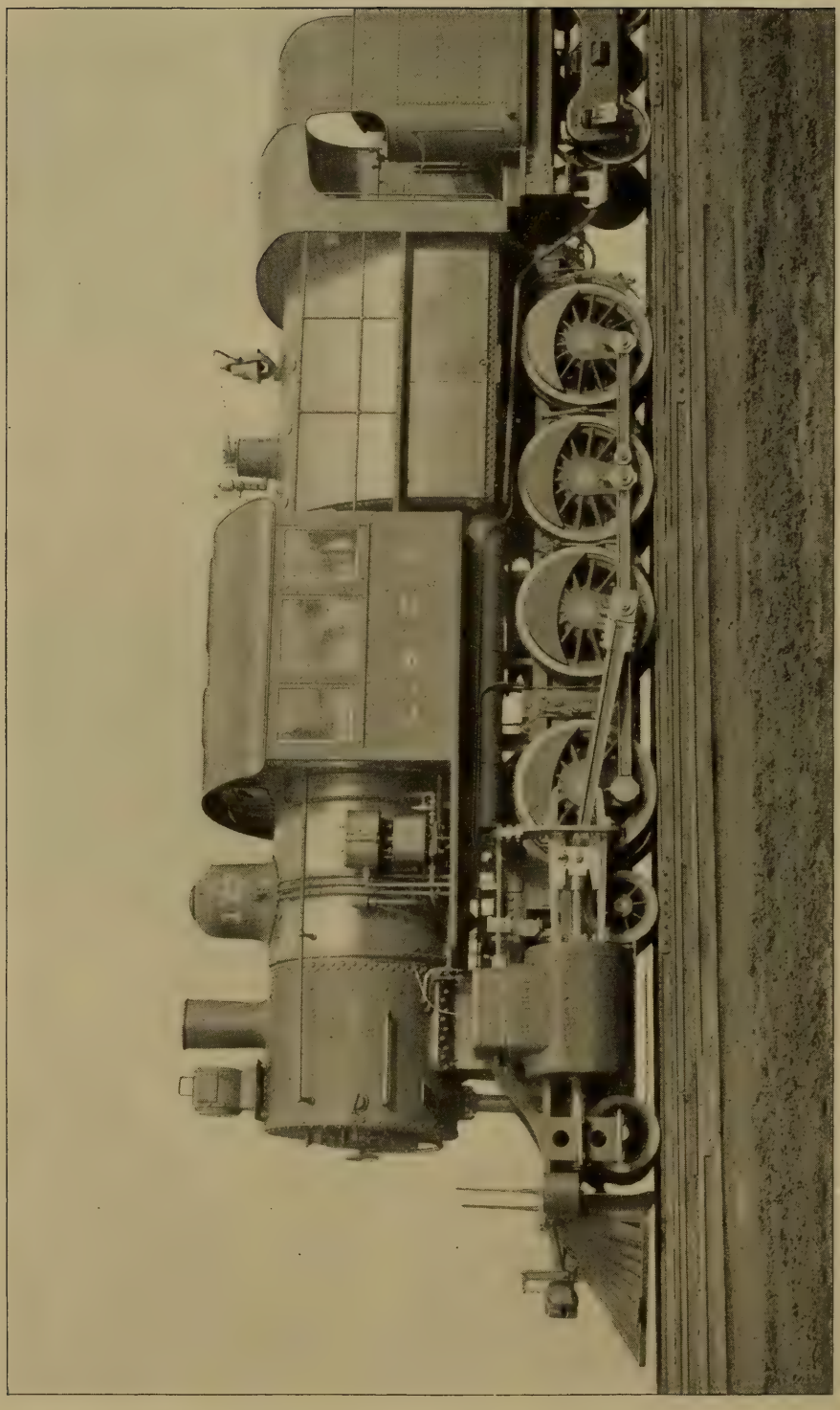


FIG. 18.—TWELVE-WHEEL COMPOUND LOCOMOTIVE BUILT FOR THE CHICAGO & EASTERN ILLINOIS RAILROAD BY THE PITTSBURGH LOCOMOTIVE & CAR WORKS, PITTSBURGH, PA. TOTAL WEIGHT OF ENGINE, 189,700 LBS. WEIGHT ON DRIVERS, 150,000 LBS.

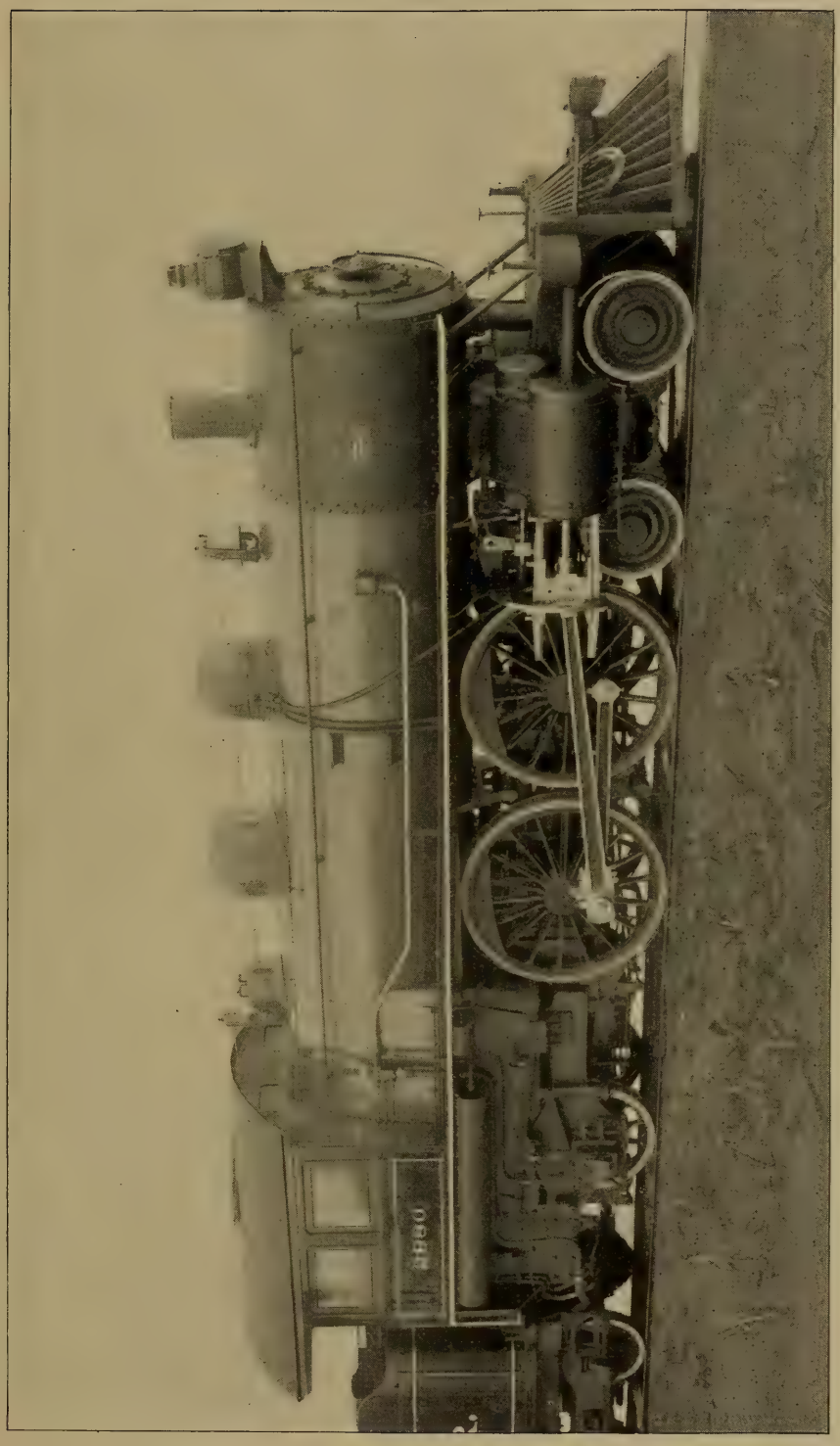


FIG. 19.—THE EMPIRE STATE EXPRESS LOCOMOTIVE ON THE NEW YORK CENTRAL RAILROAD. BUILT BY THE SCHENECTADY LOCOMOTIVE WORKS, SCHENECTADY, N. Y.

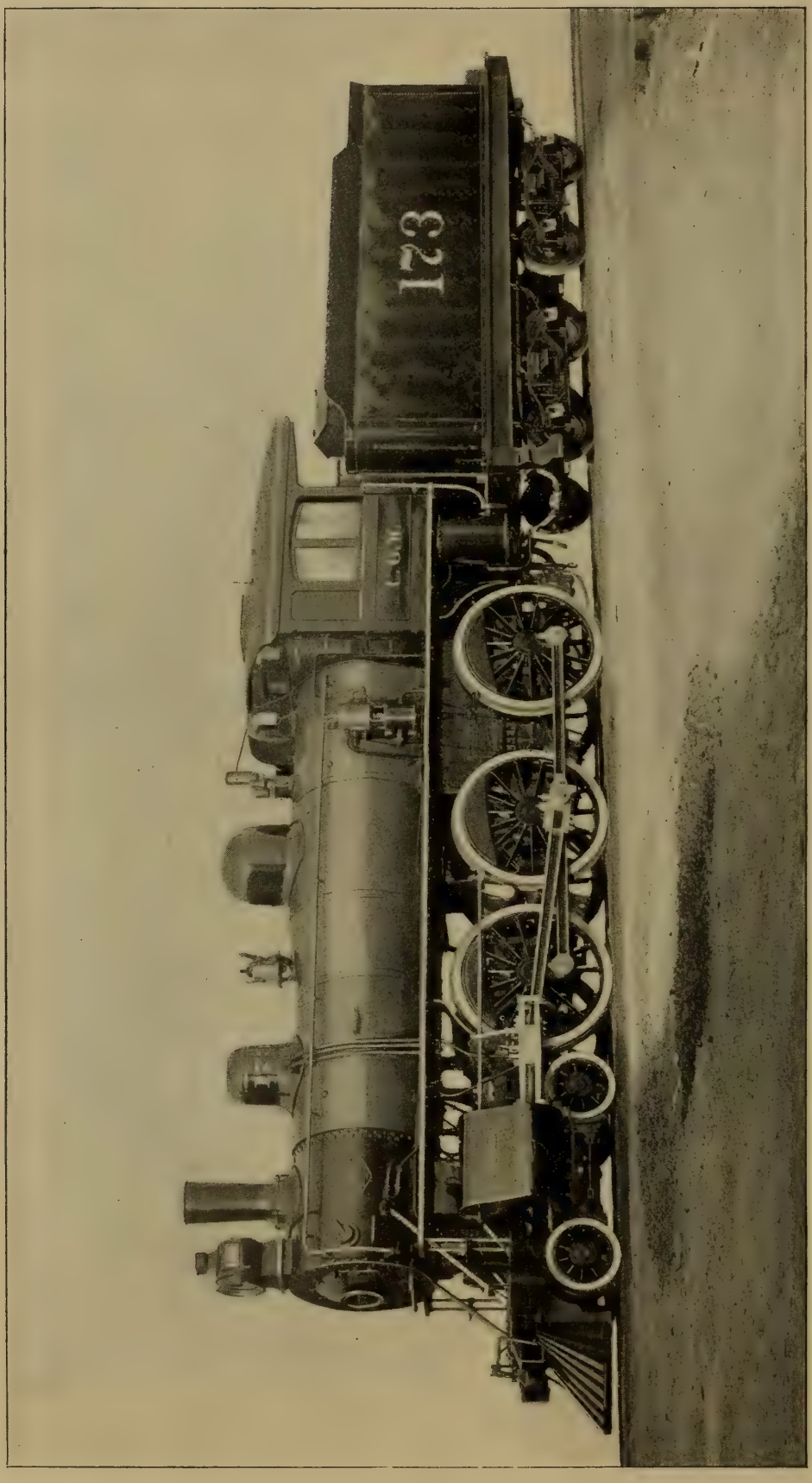


FIG. 20.—TEN WHEEL PASSENGER ENGINE WITH PISTON VALVES. BUILT FOR THE CHICAGO GREAT WESTERN RAILWAY BY THE RICHMOND LOCOMOTIVE WORKS, RICHMOND, VA.

The introduction of steel for rails in place of iron has made possible heavier locomotives, and also the gradual increase in the weight of steel rails until to day rails weighing one hundred pounds to the yard are being used, whereas, forty years ago a large part of the mileage of American railroads was laid with rails weighing less than sixty pounds to the yard, and generally of iron. Cars, too, have been increased in weight and capacity. Thirty or forty years ago a car weighing ten tons was loaded with ten tons of freight, and a heavier load than that was discouraged; important improvements in the quality of material, but have done it with an increase in the price of not more than 40 or 50 per cent. The changes in the material have been the adoption of steel for boilers instead of iron; of thicker boilers and stronger boilers, made in a much more expensive and elaborate way, so as to be capable of carrying a steam pressure of 200 pounds to the square inch, whereas thirty or forty years ago 100 pounds was the ordinary pressure. More parts are made of steel about the locomotive than formerly; tender frames are made of steel; the

FIG 21 —A 91-TON GEARED LOCOMOTIVE BUILT BY THE LIMA LOCOMOTIVE & MACHINE CO., LIMA, OHIO, FOR MOUNTAIN DIVISION SERVICE ON THE CANADIAN PACIFIC RAILWAY

in fact, double rates were charged on loading in excess of a certain amount, which was twelve tons, while to-day cars are being built to carry 100,000 pounds, or fifty net tons.

The effect of this increase in the size and speed of the locomotive and of the substitution of steel for iron, the increase in the weight of rails and in the improvement of bridges has been very largely to reduce the cost of operating the roads, and to that fact is due the decrease in the cost of transportation.

American builders have probably more than doubled the weight of locomotives in twenty-five or thirty years, and at the same time have made most tanks are made of steel; the cabs are made of steel, where they were formerly of wood. All the wheels under a locomotive and tender are steel tired, where formerly both the tender and engine truck wheels were cast iron. This substitution has been made possible by great improvements in the production of steel.

These changes are common to all locomotive works in America, but in Europe practice has been more firmly established, and they have adhered to their original standards to a greater extent. The American railroad system was built up largely on borrowed money, and had to be developed under condi-

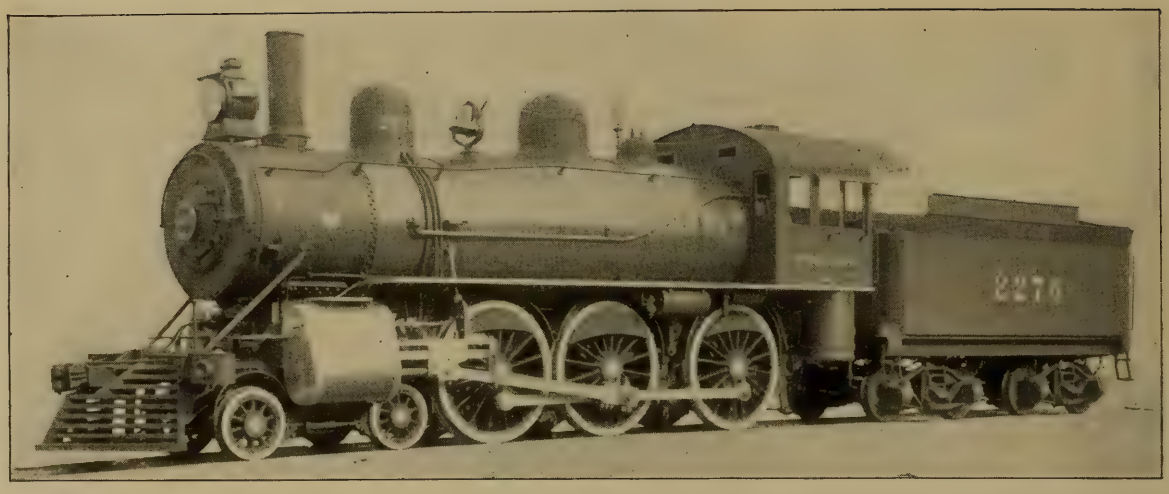


FIG. 22.—TEN-WHEEL ENGINE FOR HEAVY FAST PASSENGER SERVICE ON THE SOUTHERN PACIFIC RAILROAD. BUILT BY THE COOKE LOCOMOTIVE & MACHINE CO., PATERSON, N. J.

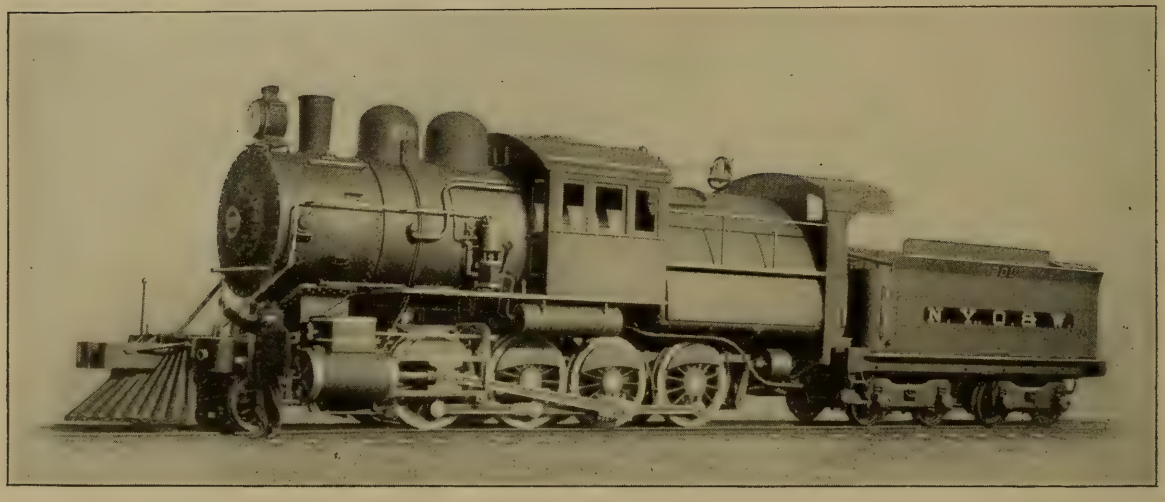


FIG. 23.—A COOKE CONSOLIDATION ENGINE ON THE NEW YORK, ONTARIO & WESTERN RAILWAY

tions of the greatest economy; light rails, wooden bridges, cheap structures had to be used in order to make it possible to stretch the railroads across the vast Western territories; but with the growth of the country and the strengthening of these great railroad lines the roads have been rebuilt, and heavier rails and better bridges and better equipment have been substituted. The locomotive and car manufacturers simply reflect the development of the country, and of its interests, and have adapted themselves to that development.

In extending the foreign market for locomotives some very high tariffs are encountered. In Russia, for example, the duty on a locomotive is four cents a pound, and is fully effective in its purpose to protect Russian manufacturers. In dealing with the Russian Government, however, the Baldwin Works, which in four or five years have supplied about 150 locomotives for the Trans-Siberian Railroad, did not encounter the tariff, as their contracts provided for delivery on board steamer at a Russian port. In the majority of foreign countries the railway system is largely governmental, and the tariff question is thus eliminated from the transaction.

As regards importing foreign locomotives into the United States, it is interesting to note that there is only a single case on record in the last quarter of a century, and that was a specimen locomotive ordered in England by the Pennsylvania Railroad Company for the purpose of serving as a pattern of a new type and of workmanship. Locomo-

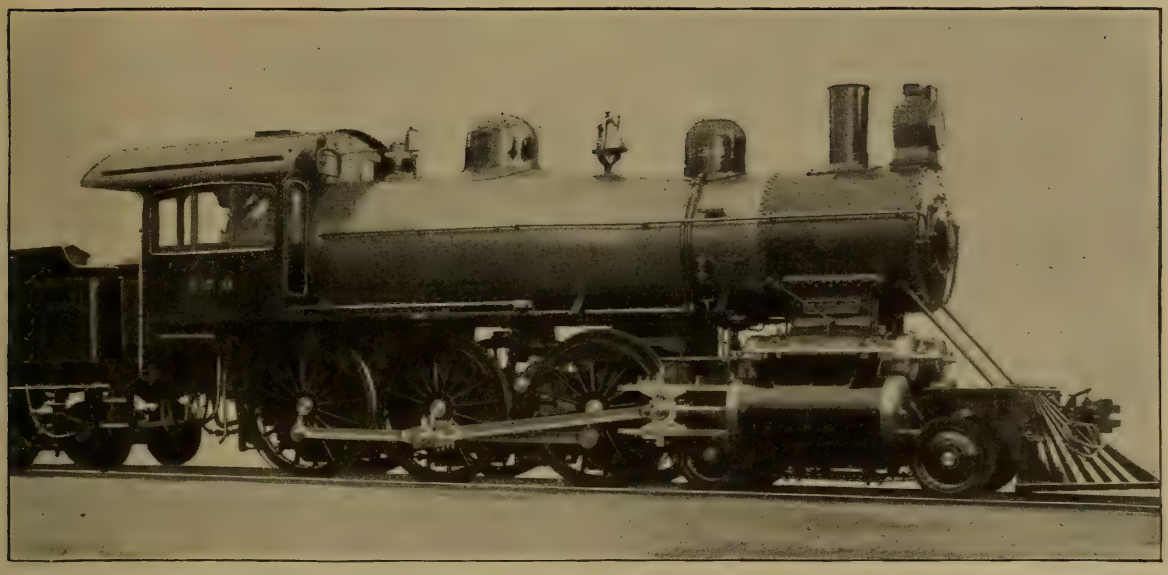


FIG. 24.—LOCOMOTIVE BUILT FOR THE INTERCOLONIAL RAILWAY, OF CANADA, BY THE DICKSON LOCOMOTIVE WORKS, SCRANTON, PA.

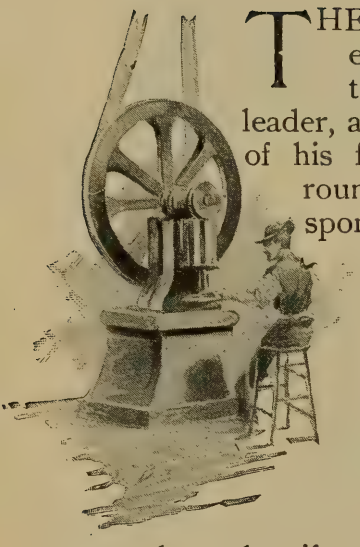
tives have been growing more and more alike in American and foreign practice.

The principal distinction between American and foreign locomotives to-day is the use in America of the bar frame as contrasted with the plate frame, which latter is a feature of European practice. American locomotives, further, are invariably built with outside cylinders, while in Great Britain and on the European Continent inside cylinders and crank axles are still used to some extent. These two details to-day represent the most radical differences between the American engine and that of other countries.

THE FOREMAN MACHINIST

THE MAN AND HIS DUTIES

By Milton P. Higgins



THE title "foreman" emphasises the idea that he ranks as a leader, a man in the forefront of his fellows. In all the round of duties and responsibilities in industrial enterprises no place is so difficult to fill, and generally none so inadequately filled, as that of foreman. I do not deny that there are many good foremen to be found in different shops, but if we compare what they are with what they ought to be, they are certainly inadequate and unsatisfactory. This is not said because I do not appreciate the foreman of to-day, but because of my high appreciation of the position and duties of the ideal foreman, because I realise the vital importance of his duties in the success of a business, because of my conception of the great demands made upon him, and because of the failure, within my observation, of men who now occupy these positions, to appreciate either the importance, the demands, or the opportunities of their calling.

The foreman must come into most vital, directing, and leading contact with almost every individual in the working force of the factory. His relations and influence with both his superiors and those who are under him demand superior qualities of judgment and executive ability. A very slight reduction in his efficiency, good judgment, and executive ability is sufficient to change the yearly balance sheet from profit to deficit. This fact is enough to establish the high importance of the position in a commercial way. Besides this direct commercial consideration, no man in the entire establishment is in a position to influence so effectively for good or evil the harmony and happiness of the entire force of workers.

The foreman's education and knowledge must be thorough and broad along the line of his work. He is called upon to handle figures quickly and accurately; he must read drawings clearly and exactly, which means that he must have the knowledge of the draughtsman, if not his skill, though the skill would be of real value to him. He is called upon to judge wisely of the metals and other materials which he works. No other position in the works demands so ready knowledge of mechanics and natural philosophy as that of the foreman of the machine shop. Almost every operation, fine and coarse, from the time the heavy castings are unloaded upon the floor till the shipment is made, requires of the foreman a knowledge of the theory of physics and mechanics. For example, he must be able to estimate quickly the weight of heavy pieces and the approximate strength of ropes, and chains, and hoisting gears, so that heavy bodies may be handled with safety and rapidity.

But the greatest demand is upon the foreman's ability for choosing the best method of working the material for the various parts of machines. It is easier to allow a workman to use a poorer method and to push him hard than it is to study to adopt a better method which will halve the cost of his product without overworking him. The foreman should control the method of working the metal into shape. By method I

mean the process of tooling any particular piece, whether it be chipping, filling, turning, planing, milling, or grinding. Let any one think of the production of any machine part and he will find there are always many ways of doing it, all very different in their nature. Every one of these ways may be still in use to-day in different shops, and possibly every one may be desirable under certain conditions. This being true all along the line of machine operations, what an infinitude of choices a shop foreman must make, and what a great difference in costs it will make whether he chooses wisely or not.

This brings us to the all-important subject of costs, which can be only barely touched upon here. No matter how complete the office system of costs may be, the foreman must have minute knowledge of his own of costs. In order that he may compare the work of one man with that of another, in every piece that is made and in every different method used, and thus be able to fix the pay rate justly and know which method is cheapest and best, this detailed knowledge of costs must always be kept by the foreman. It is not enough for him to know the comparative costs of complete machines; he must know the cost of the smallest machine parts.

The skill of the foreman, though not mentioned first, is of first importance. The ideal foreman can do skillfully and expertly everything that he demands of his workmen. Hence, he must be a master among his men, in skill as well as in knowledge. Showing is often more important than telling, and it makes the telling very effective indeed.

The foreman must also have been born a leader. The qualities of leadership, so necessary to the successful man in this position, are matters of natural gift. To obtain the born leader is a matter of natural selection, that is, the foreman must be chosen from a great number of men equally skillful and educated. But leaders always exist, and may be chosen by well-known qualities which manifest themselves whatever the position in which they are found. If a lot of men or boys be cast away at sea, as soon as ten of them have climbed upon a raft and brushed the salt water out of their eyes, one out of the ten will be telling the other nine what to do to be saved and showing them how to do it, and, almost without realising it, every one of the nine will be asking him what to do next. Natural laws take care of this quality; but we must find the material for such a man, and it requires a large number of first-class expert machinists from which to choose.

The great trouble is that we do not get good, superior material enough into the shops to learn the trade. We see good leaders in other lines, but they are without skill or knowledge in the machinist's trade. I think there is not more than one born foreman in a hundred good machinists, and as we have to have a foreman to every fifty machinists, and as those from whom we choose are not by any means all first-class machinists, we naturally get many poor foremen. We cannot impart the qualities of leadership, but we can select boys who exhibit these qualities and impart skill and knowledge to them. If the learning of a trade could be made more attractive and the opportunity in it brighter, we would get more of the material which we need to meet this demand.

Thus far the writer has tried to show that the foreman should be a skilled mechanic, with a thorough technical education and the qualities of leadership. But this is only a part of what he should be. He might have all the above qualifications and not be a manly man, with the character of a gentleman. This demand upon the foreman is not for sentiment,—it is for success in the shop. It is necessary for dividends and for supremacy of industry. Workmen cannot be forced to do right or to produce their best; they must be influenced to do so. Where can you find many men called upon to deal with so large a number of men of such varied and diversified temperaments? It requires a good man to influence men for good. If character and culture count in legislative halls, in the

courts, and in the pulpit, why is it not important in the workshop, where there are more men than in all the churches, courts, and lecture-halls combined?

The demands upon the foreman require him to handle his men so that the largest output shall result without reducing the quality of the work or the manhood of the men. This latter duty is most important. He should strive to preserve the rights of every workman, and, if the best results are to follow, he must see that neither the men's rights nor their happiness are lost sight of at any time. For example, the shopman is often sensitive to his surroundings, such as temperature, light, noise, and the like, and attention to such details by the foreman is of great benefit in the shop.

It is the foreman's imperative duty to be kind, patient, and helpful to all who approach him for aid and information regarding the work in hand. Because a worker is slow and dull, and asks seemingly unnecessary questions, the foreman has no right to crush his spirit, rouse his anger, or cause him to feel humiliated by silent scorn or by condemnation. There is nothing that a foreman can do which works greater harm and so greatly hinders his success as any bearing toward men and boys that gives them just ground for dislike or revengeful determination to get even as soon as an opportunity offers. I am not advocating a flimsy, weak treatment of workmen. That is neither necessary nor successful. The treatment may be strong and exacting. The foreman may expect and demand a great deal of his men, even more than the average of other shops, with perfect success, provided his spirit and the principles of his life are justice, fairness, and a kindness that always go with good-will toward men. A good test is to put yourself in the worker's place and treat him with absolute justice.

Perhaps the greatest hindrance to the success of a foreman is a bad disposition. This is largely due to a lack of self-control and self-discipline. Disposition can be changed and improved when one gets the right conception of life, duty, and method. Even a man endowed with perfect physical health, natural mechanical ability, and executive energy, with a good understanding of shop methods and more than an average education, may have his success as a foreman blighted and hindered by a bad disposition toward his men and others who are obliged to come in contact with him.

Good conditions and just conditions are necessary for a foreman's success, and this must be brought about by him by the cultivation of things desirable, a sort of evolution that can never take place with an overbearing foreman. The work of the future foreman will be to teach rather than to govern, and a good teacher must know both his subject and his pupils. Then he will succeed in proportion to his love for his subject and for his pupils. All the men composing the working force of the shop are the foreman's pupils. If he be wise, he will learn much from each and every man. He will also study and think a great deal to keep up with modern methods. His part is to put all the latest and best information pertaining to the skill of the trade into suitable shape to be imparted to each man as he needs it. If the standard of the shop is to be raised, each man must be taught constantly by the foreman to do work both better and quicker.

The foreman's business is not that of general superintendent, nor is it that of inspector of work merely. He must, however, stand very near each and every man, constantly imparting skill and knowledge, both by precept and example. The foreman and the men must work together to determine the maximum speed and feed. Simply saying, "Increase your speed or feed," will not accomplish the desired result. A machinist is usually convinced and ready to argue that any effective increase is impossible, while a good foreman can prove it to be practicable with his own hands. The selection of a better tempered tool steel, a better lubricant for drilling or cutting, is a matter of actual test, and generally a test of a higher

order than the workman will ever make unaided.

So much is said regarding the very close and intimate relations of the foreman and workman in the shop because of the belief that the possibilities for advancement here are much greater than they are generally thought to be. I wish now to speak of the necessity of some intimate relation with the life of the man outside his actual work. We cannot afford to know so little of the life of our men outside of the ten hours during which they are with us. The foreman should not be regardless of the social life of the workmen. Some will say, "Business is business." Be it so. I will base what I have to say entirely upon business considerations, upon the sole ground that it will pay to do right, and that no considerable success can follow a wrong plan of conducting shops. It is true that men are not in a shop for social relations; they are there to perform certain labours for which they are paid. But there are social relations, nevertheless, in the machine shop and outside, that are important and even essential to the best work.

The shop-work side of a man is only one part of his life, and without right relations in the whole life this part will not score its proper success in production for the employer. Since work is the expression of the man, how important it is that the foreman should know as much as possible of the man behind the work and something of his whole life and the struggles he has. We may justly expect all sorts of troubles in our shops if the workman's home life is of so little interest to us that the first cradle is brought into his home and the first little coffin carried out without the foreman knowing why the man is out of the shop, while his work, which is so badly needed, remains at a standstill. Let no reader accuse me of lugging in considerations that do not belong to the business interests of a shop! I insist that such considerations are necessary to success.

It seems to me that police stations are sometimes managed very badly because in the hands of those who hate and despise men. Few of those for whom police stations exist are habitual criminals. A little help and encouragement, prompted by a love for one's fellows, would make these catch basins of drifting humanity reclaiming works of the lives and souls of men. Shops should be conducted by those who love men and believe in them. By those who understand their lives, their struggles, troubles, pleasures, and ambitions. By those who see the worker as an individual rather than as a mere fraction of the "help."

If men are inspired to be better men, they cannot help being better workmen. But it is doubtful if we can inspire another to be better than we are ourselves. If this be so, how well it pays to have a superior foreman! He fixes the standard for the entire force. If the general level of efficiency be raised a little, the net gain will be very great, and right here lies the difference between success and failure.

How can a foreman find time for so much? It is not much outside his shop duties. It is largely a matter of disposition. Cultivate an interest in the men's lives, manifest some interest in the man, other than in his actual productions in the shop, and the rest will be plain and easy. The dress of the foreman is of sufficient importance to mention. There is the greasy foreman who never wears overalls, and the foreman who always wears the same good coat in the shop and on the street. He does not get much soiled because he does not get very near the men or the work. Then there is the white-aproned foreman, and the long-coated foreman; but the best-dressed foreman wears overalls that are of ample size, so well washed and pressed once a week that they are a comfort to the wearer and a satisfaction to all who meet him. This allows him to be in the shop all day, with no shrinking fear of getting soiled, and when he puts on his coat and goes out he may be as well dressed as the president or treasurer of the works.

What are the inducements for good machinists to strive to become competent foremen? This is an important

question. Suppose a foreman gets 50 per cent. more pay than a machinist, that certainly is one attraction, and the satisfaction of having responsibility is another. But add to this a reasonable faith and hope of taking a position and rank as a foreman more advanced than any heretofore known, and that is, I think, a very great inducement for able young men to fit themselves for mechanical foremen.

The field open to a superior skill and ability in this position is great and promising. Although the wages of of the foreman to-day are not very large, it is chiefly because there are no men in the market worth a higher price. There is surely a strong and a growing demand for more capable, and, therefore, higher-priced foremen. But we must remember that high wages will not generally produce the required men. The superior men, when they have shown themselves capable, will receive the higher pay.

If labour organisations are ever to get beyond the lowest idea of labour, they must follow the plan of inducing the individual to do all he can instead of trying to see how little he can do. How do we ever get superior results? How do masterpieces come about? Not by a contracted sense of duty, or by being driven to work, but by a life absorbed, immersed in the passion for the art or the work in hand.

This love for work, this passion for machinery, is one of the great needs for success in the future of any country. The field is so important in the competition in the world's market that I wish some rich man would establish a college that would attract the best talent of the wealthy and cultured. Not that I think that rich men's sons will make better mechanics, but they sometimes have inherited ability, and can get the best mental discipline such as we need in the shops. The opportunity for the future foreman certainly seems, indeed, broad enough for the best young men in the land.

SOME AMERICAN TURRET LATHES

By Peter J. Connor

THE position occupied by the turret lathe in manufacturing operations may be compared, in a measure, to the one occupied by the milling machine, in that they are both largely used for the production of duplicate or repetition work, and their best results are obtained in establishments where the output consists of goods made on what has been termed the "American," or manufacturing, plan.

It is unnecessary to refer to the early history of the turret lathe in this article, as the object is to present to the readers of this magazine the very latest productions of well-known makers of this class of machine tool, rather than to give a record of past work in the field. The benefits resulting from the adoption of tools of this class have been universally recognised by manufacturers in all lines of machinery where their use is at all possible, and has resulted in the production of better articles, of a more uniformly standard grade, and at a greatly reduced cost.

It is the custom of makers of this line of machines to invite prospective customers to send samples of drawings of the kind of articles they propose to adapt the lathe to produce, and then to make an estimate of the cost of the special tool outfits required to do the work, and they also usually guarantee the time in which the desired work can be accomplished. In this feature of modern machine-tool building they differ from makers of standard lines of tools, such

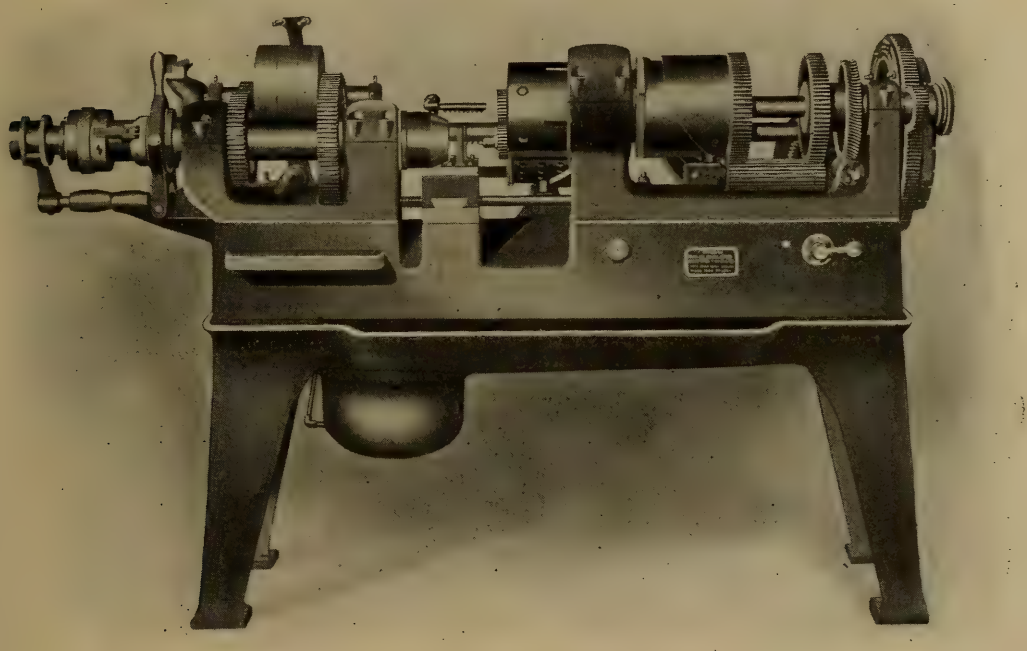


FIG. 1.—TWO-INCH AUTOMATIC TURRET LATHE BUILT BY THE CLEVELAND MACHINE SCREW COMPANY, CLEVELAND, OHIO

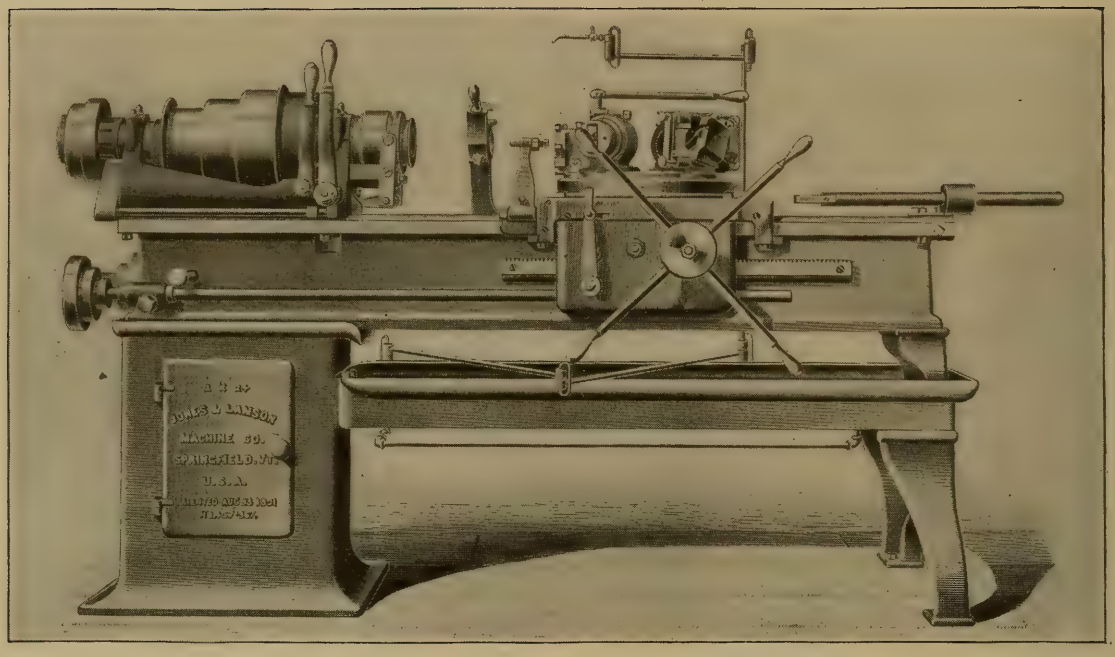


FIG. 3. FLAT TURRET LATHE MADE BY THE JONES & LAMSON MACHINE CO., SPRINGFIELD, VT.

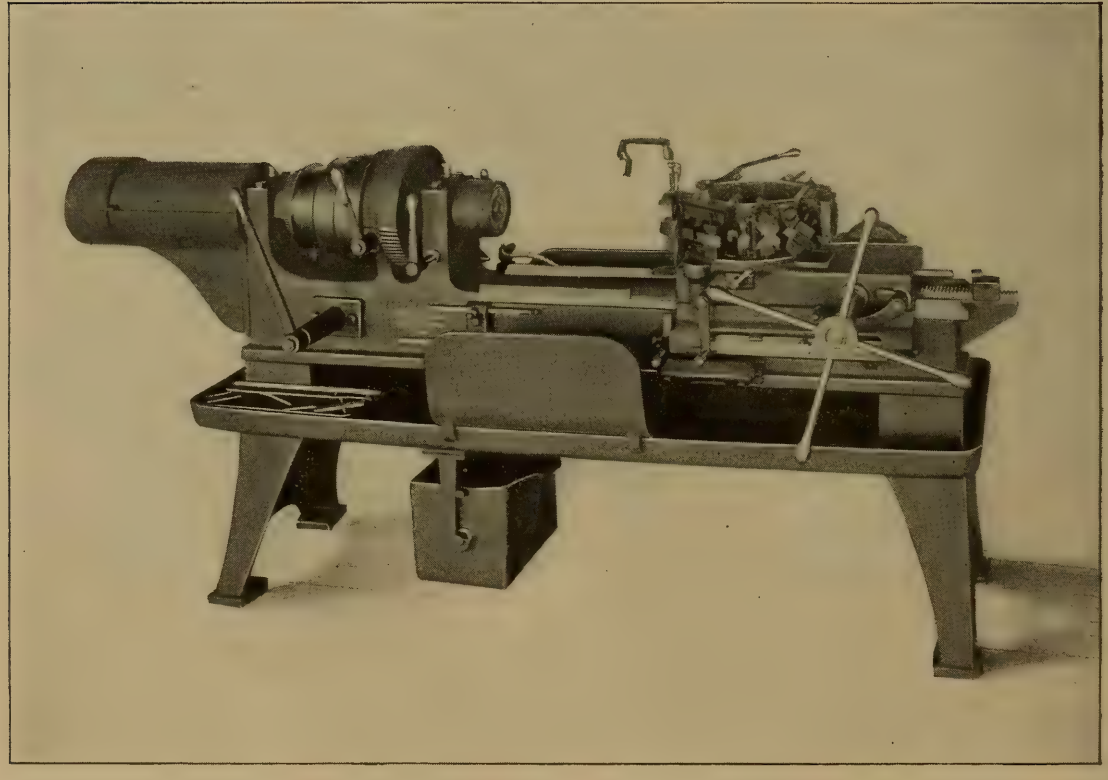


FIG. 4.—HOLLOW HEXAGON TURRET LATHE. CAPACITY, 2 INCHES DIAMETER, 24 INCHES LENGTH. BUILT BY MESSRS. WARNER & SWASEY, CLEVELAND, OHIO

as lathes and planers, as the latter are rarely called upon to furnish the cutting tools to be used on their machines.

The manufacture of turret lathes has reached such magnitude that there are several concerns in America whose output consists principally of this product, while they are made by many other firms who also make other lines of machine tools. But their adoption has not been confined to America alone; they are being largely introduced into European countries, and nearly all the American makers are represented by European agents, besides having direct representatives and skilled operators abroad. The machines generally may be classified somewhat after the following manner:—

1.—Full automatic machines, in which the operator is required only to supply the stock and see that the tools are doing their work properly.

2.—Semi-automatic machines, in which all the operations are directly under the control of the operator.

3.—Hand-operated screw machines.

4.—Chucking and facing machines, used largely for boring, facing and turning castings, etc.

Examples of the machines considered under the above classification will be shown and briefly described. The machine shown in Fig. 1 represents the latest automatic machine produced by the Cleveland Machine Screw Company, of Cleveland, Ohio. It embodies many striking and original features, and a comparison of the cut with those to follow shows many departures from the usual practice. The method of placing the tools in the horizontal turret, the feeding mechanism, and the generally fine lines on which the machine was designed, make it an excellent specimen of the best practice to-day. It is furnished with slotting attachments, cutting-off rests, and many other devices to enable it to produce an almost endless variety of bar stock work.

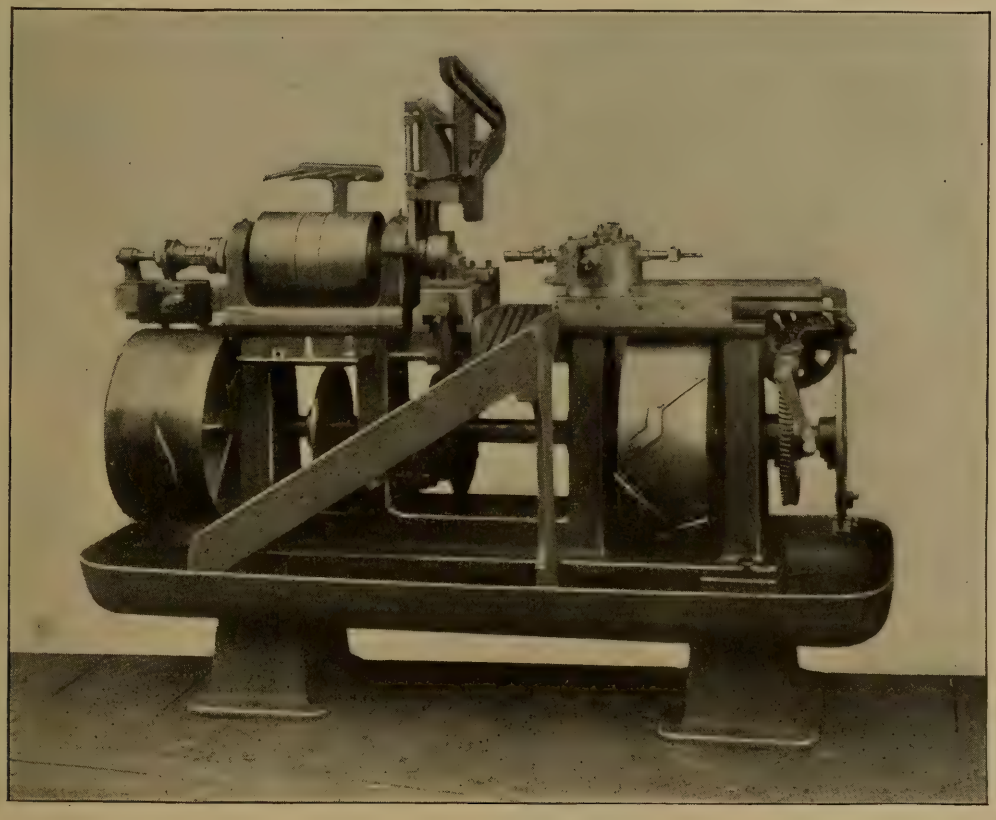


FIG. 2.—AUTOMATIC SCREW MACHINE WITH MAGAZINE ATTACHMENT. BUILT BY THE PRATT & WHITNEY CO., HARTFORD, CONN.

The machine shown in Fig. 2 is a product of the Pratt & Whitney Company, of Hartford, Conn., and is termed

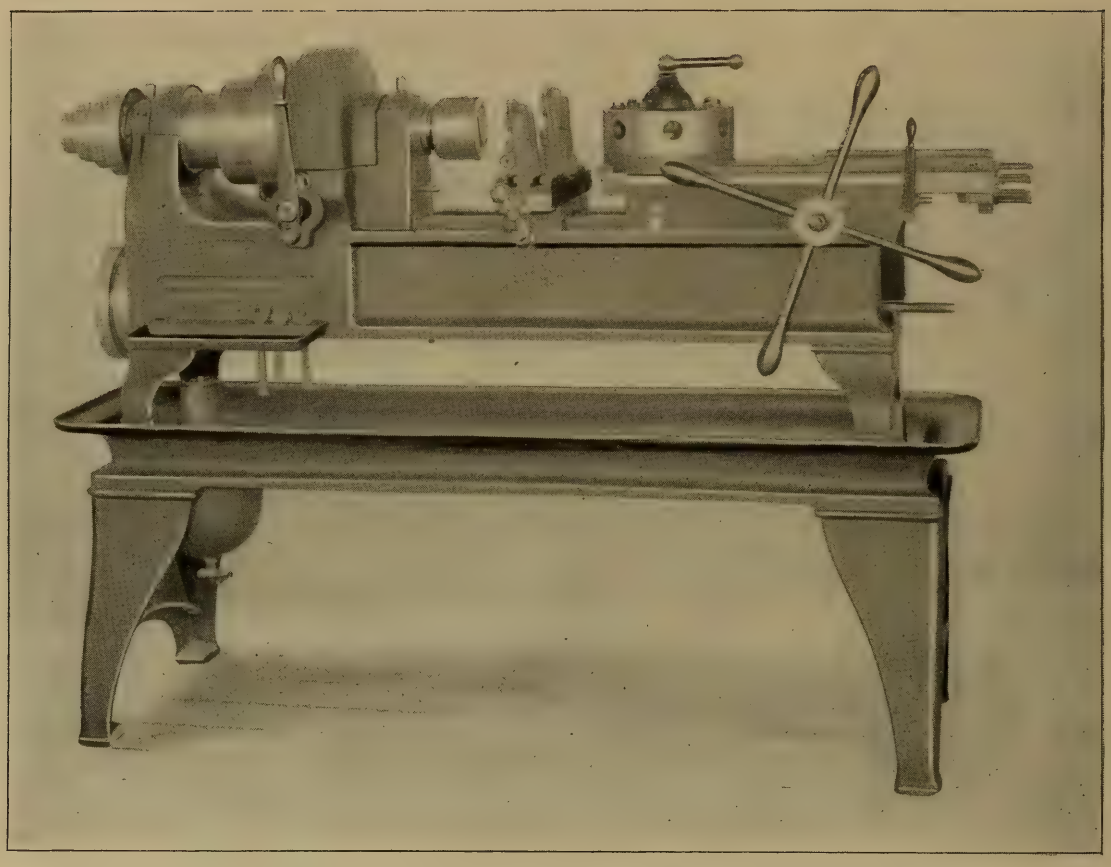


FIG. 5.—SCREW MACHINE MADE BY THE BROWN & SHARPE MFG. CO., PROVIDENCE, R. I.

a No. 3 automatic screw machine with magazine attachment. It is a full automatic tool, including the withdrawing of the rough blank from the magazine, placing it in the chuck and performing such operations as drilling, facing, reaming, grooving, and others, and taking the finished pieces from the chuck. The total time required for operating on a piece is four and one-half minutes, and one man and a boy will care for twelve machines.

FIG. 6.—VALVE BODY MADE ON ABOVE MACHINE

Fig. 3 represents the 2″ × 24″ flat turret lathe made by the Jones & Lamson Machine Company, of Springfield, Vt. With the advent of this machine on the market a great impetus was given to the turret lathe as a machine tool, as its design and the manner in which the tools are held, and the various ingenious tools, stops, feeds, etc., show the attention which the subject received by the inventor. The improved roller feed, and placing the tools on a large, flat, revolving surface, are among some of the points of excellence claimed for this machine.

Taper turning attachments may also be used, and the use of broad cutters for forming handles show the power the headstock gearing can exert on the work. The machine is manufactured in one size, with a capacity of 2 inches diameter by 24-inch length.

The machine shown in Fig. 4 is built by Messrs. Warner & Swasey, Cleveland, Ohio, and is rated at 2-inch diameter chuck capacity by 24-inch length of work to be operated upon. In this machine we have an example of increased size of hexagon turret, while the weight is reduced by removing the material from the inner part of the turret and leaving six parallel walls on which to bolt the tools. Advantage of this feature is taken by the builders in the fact

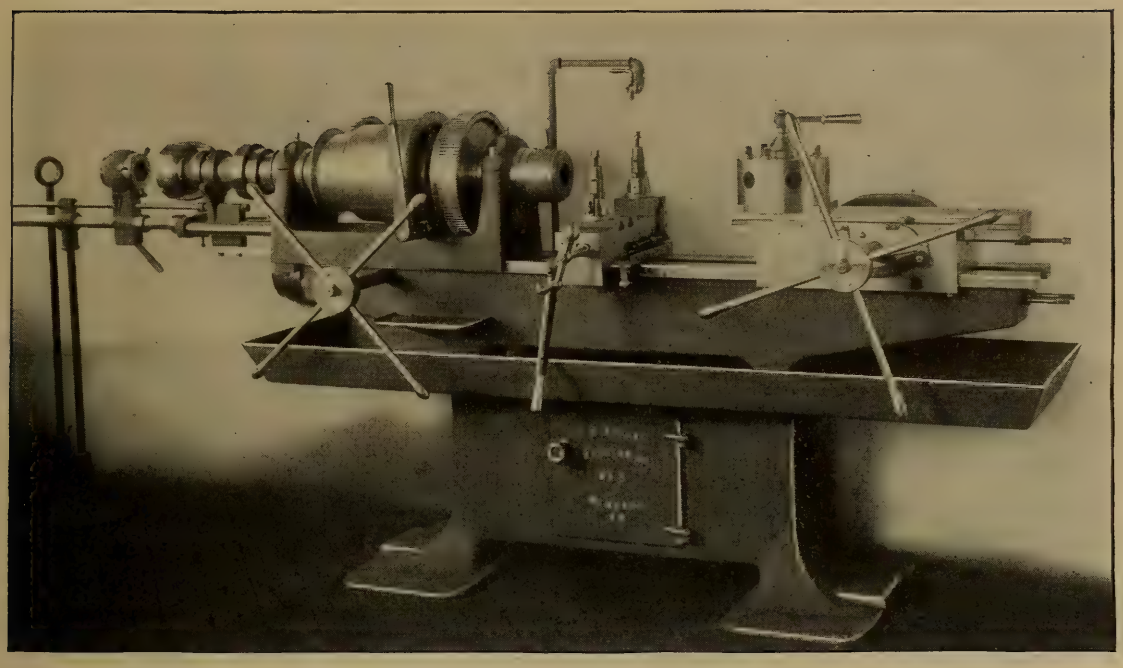


FIG. 7.—SCREW MACHINE BUILT BY THE WINDSOR MACHINE CO., WINDSOR, VT.

that they can bolt the tools from the inside of the turret, allowing more room to provide tool holders than could be given if the tools were bolted from the outside. The rotating stops for turret faces, improved chuck collets, and heavy gearing and feeding mechanism are also important features of this type of lathe.

Fig. 5 illustrates a screw machine made by the Brown & Sharpe Manufacturing Company, Providence, R. I., and is fitted with special tools for finishing the valve body, shown in Fig. 6. This valve body, a drop forging, is held in special chuck jaws, and twenty-four operations are performed on it before it is completed. The limits to which the work must be done are very close, and the correctness

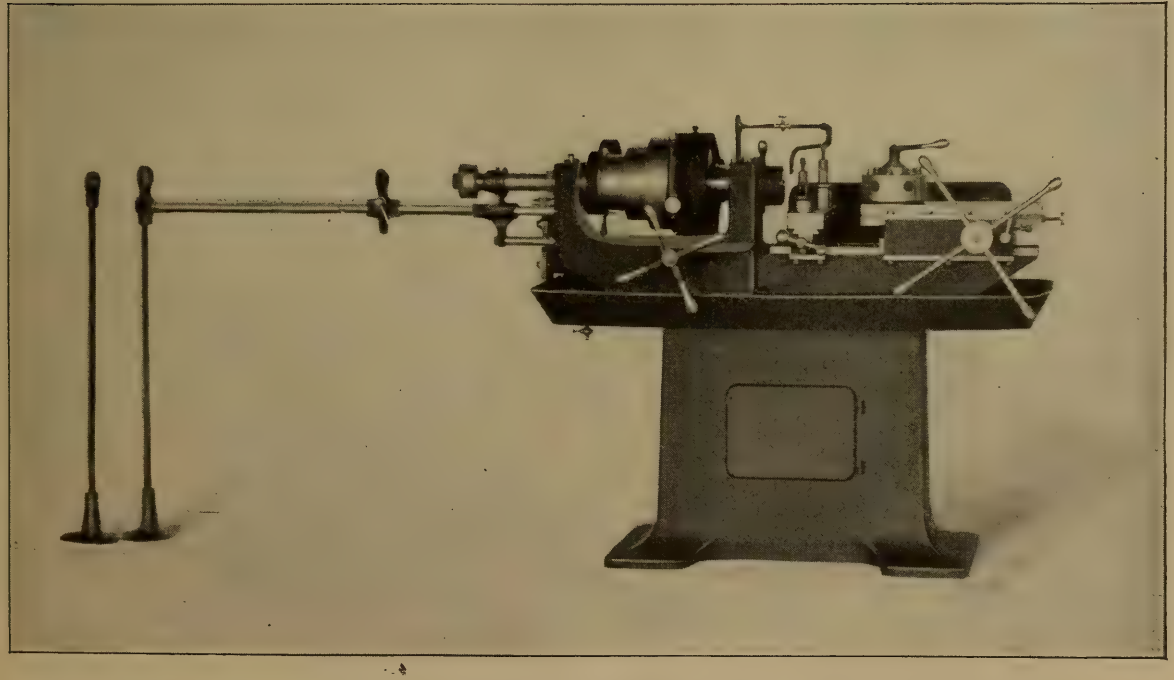


FIG. 8.—TURRET LATHE MADE BY MESSRS. BARDONS & OLIVER, CLEVELAND OHIO.

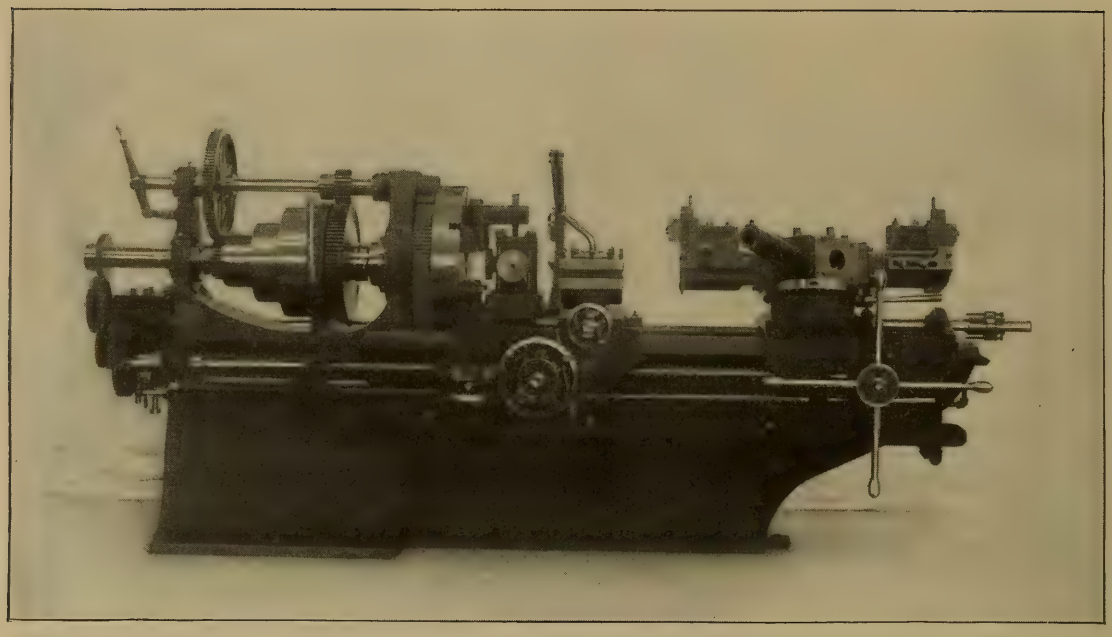


FIG. 9.—TURRET LATHE BUILT BY THE GISHOLT MACHINE CO., MADISON, WIS., U. S. A.

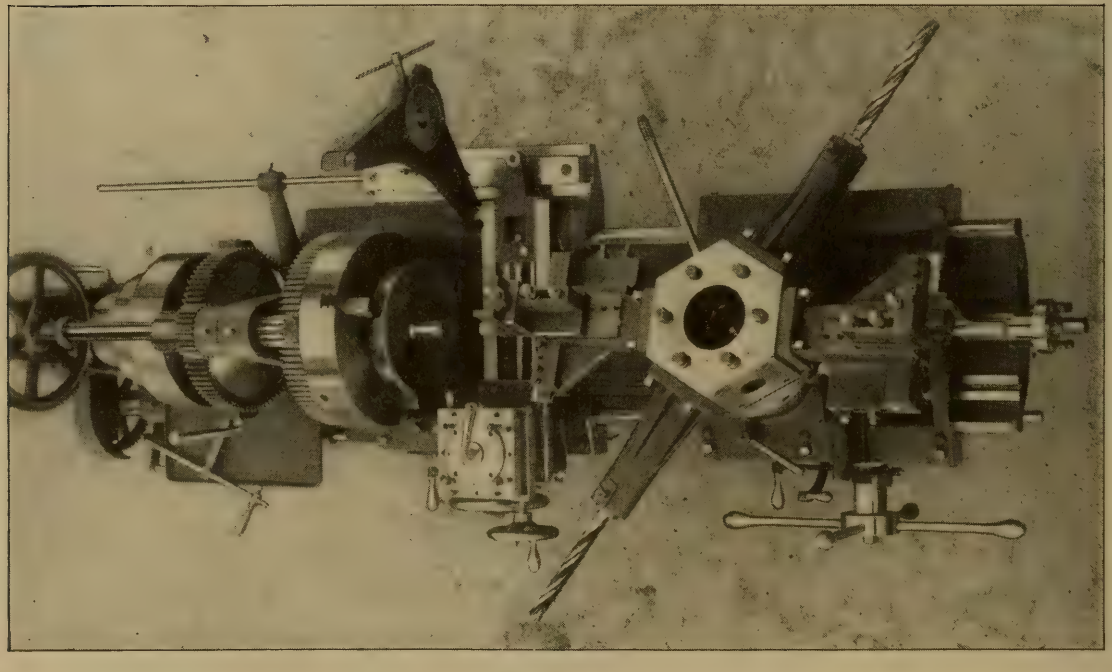


FIG. 10.—A TOP VIEW OF THE SAME LATHE

of location of the side nipple and the interior finished parts must be assured. This machine and its outfit of tools form a very interesting example of the possibilities of such work.

The machine shown in Fig. 7 is the product of the Windsor Machine Company, of Windsor, Vt., and represents their No. 5 screw machine with friction-geared headstock, automatic chuck, wire feed, etc. It is a development of the early form of the hand screw machine, combining all the improvements suggested by long experience of its makers.

Fig. 8 represents the No. 4½ turret lathe made by Messrs. Bardons & Oliver, Cleveland, Ohio, and is rated as 1¾-inch chuck capacity. Provision for retaining the alignment of the turret with the headstock spindle is made by means of gibs under the slide. The

cross slide shown in the illustration is operated by hand, but a power cross-feed motion can be attached to the machine and blank formed work done successfully. The machines are made in a variety of sizes, and are adapted to the heaviest work within their range. Ample provision is made for supplying oil. A friction-geared headstock is provided, and a double-friction countershaft is also used. These last two machines represent a very popular type of hand-operated screw machine, and are adaptable to a great variety of work.

As a result of the success attending the introduction of the smaller sizes of turret lathes for use on bar work, the application of the turret principle to

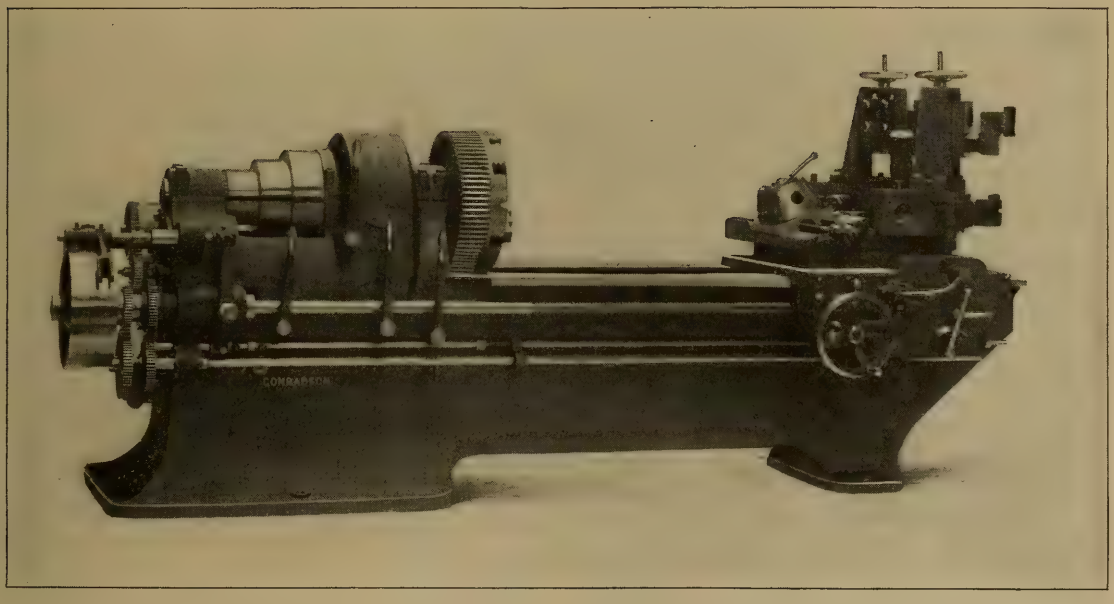


FIG. 12.—SEMI-AUTOMATIC TURRET LATHE BUILT BY THE AMERICAN TURRET LATHE COMPANY, WILMINGTON, DEL

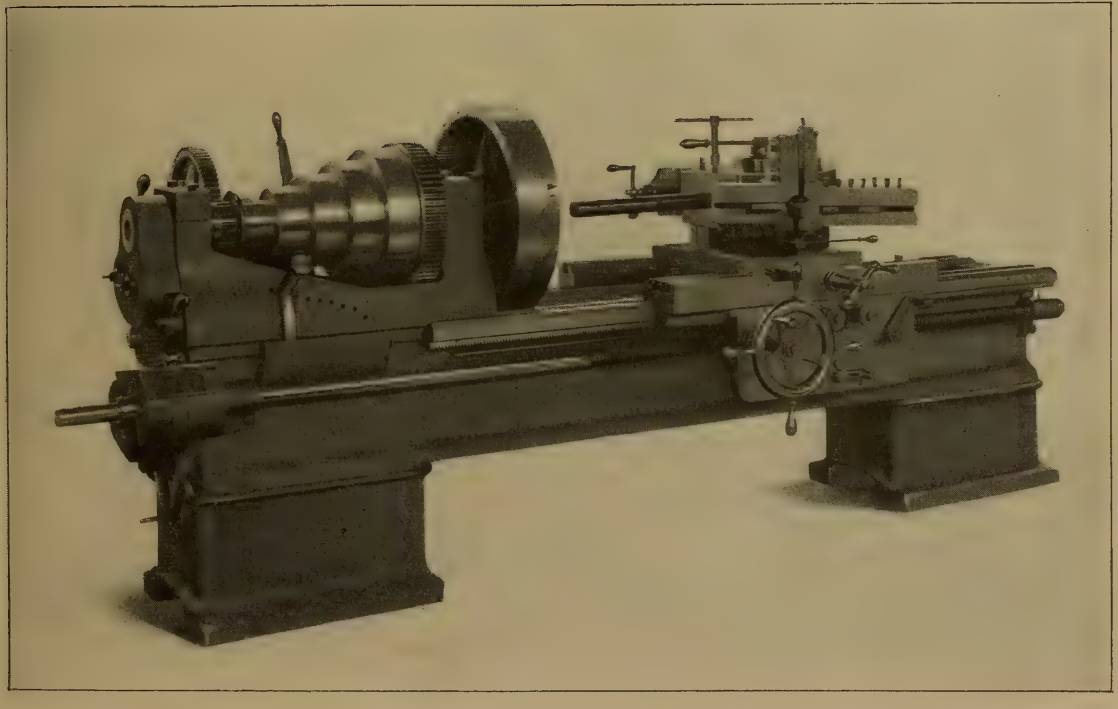


FIG. 11.—A COMBINED TURRET AND CARRIAGE LATHE BUILT BY THE LODGE & SHIPLEY MACHINE TOOL COMPANY, CINCINNATI, OHIO

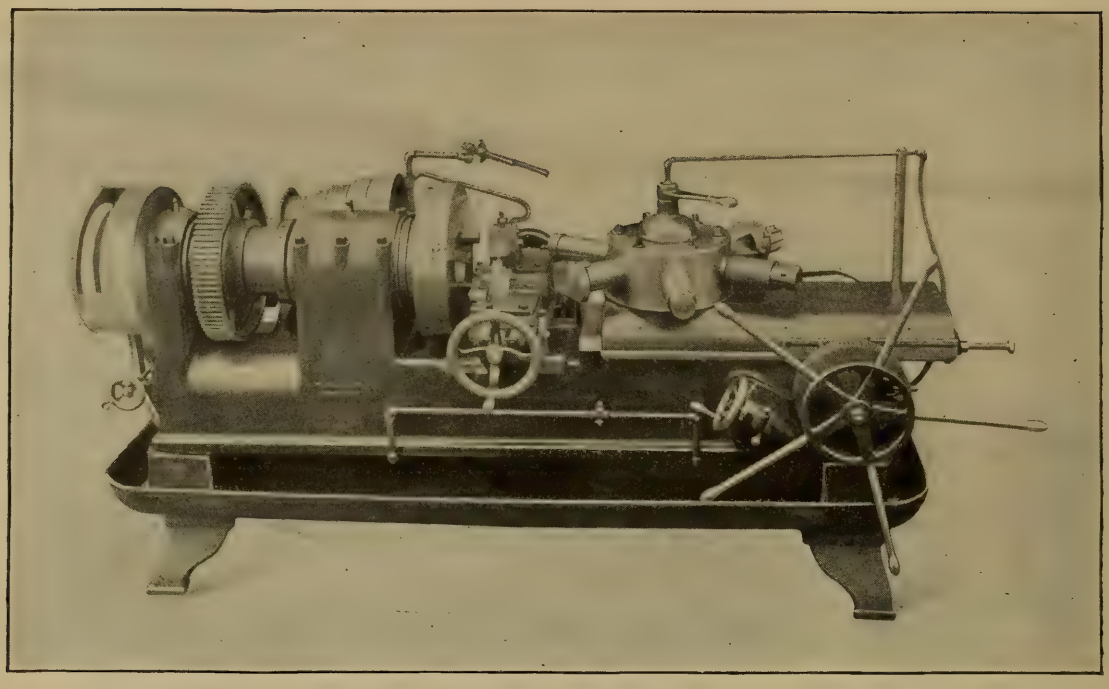


FIG. 13.—TURRET LATHE WITH FORMING FIXTURE AND TOOLS FOR AUTOMOBILE WORK. BUILT BY THE PRATT & WHITNEY CO., HARTFORD, CONN.

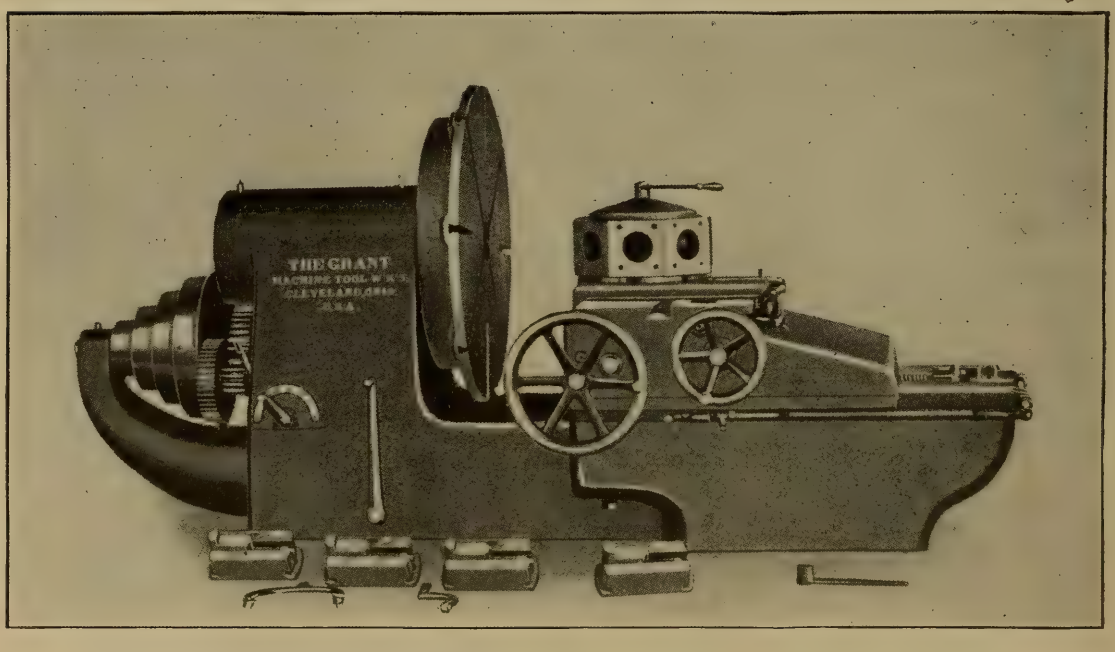


FIG. 14.—HEAVY CHUCKING MACHINE BUILT BY THE GRANT MACHINE TOOL WORKS, CLEVELAND, OHIO

heavier machines for finishing larger forgings and castings followed, and several illustrations are, therefore, here given representing some of the latest efforts in that line. Fig. 9, for example, represents the standard type of turret lathe built by the Gisholt Machine Company, of Madison, Wis., who were among the first to realise the possibilities of this method of producing duplicate work at greatly reduced cost in comparison to the single-tool method of ordinary engine lathe practice, and who for several years past have confined themselves to the manufacture of lathes of this type.

The machine embodies many interesting features, prominent among which may be mentioned massive proportions, large gear ratios in headstock, independent turret and carriage, devices for instantly changing feeds, independent stops, etc. The lead screw used is of very coarse lead, and serves also as a means of moving the carriage quickly.

The machine shown in Fig. 11 is made by the Lodge & Shipley Machine Tool Company, of Cincinnati, Ohio. It is a combined turret and carriage lathe provided with powerful gearing and the well-known devices for changing the feeds quickly as made by this company and used on their standard engine lathes. The capacity of this machine is 24 inches swing; an extra heavy chuck is used. The tools used for finishing the work, such as facing heads, boring bars, and independent cross-slide, are shown on the turret.

Fig. 12 shows one of the more recent machines, placed on the market by the American Turret Lathe Company, of Wilmington, Del., and rated as a 40-inch, semi-automatic turret lathe. The general tendency toward increased sizes in machine tool details is well illustrated in the design of this machine. The turret and cross slide are combined, and are traversed and rotated by power.

The machine shown in Fig. 13 represents a special-type turret lathe made by the Pratt & Whitney Company, of Hartford, Conn., and is fitted with special tools for automobile work. This machine is rated as 7¾-inch capacity, and is provided with a turret slide fitted directly to the bed, automatic feeds, independent tool carriage, oil pump, and other accessories. The headstock cone in this machine is carried on a shaft at the rear on account of the large spindle capacity. The slide is carried directly on the bed, and provision is made for supplying oil to the centre of the turret for drilling.

Fig. 14 shows a machine built by the Grant Machine Tool Works, of Cleveland, Ohio. This is rated as a 44-inch chucking and turning machine, is a very substantial tool, and can be considered as a type peculiar to itself. The location of the driving gears, form of bed, and the combination of the turret and carriage may be mentioned. Holes having a taper of 3 inches or less may be bored by swiveling the slide on its base to the desired angle. The slide

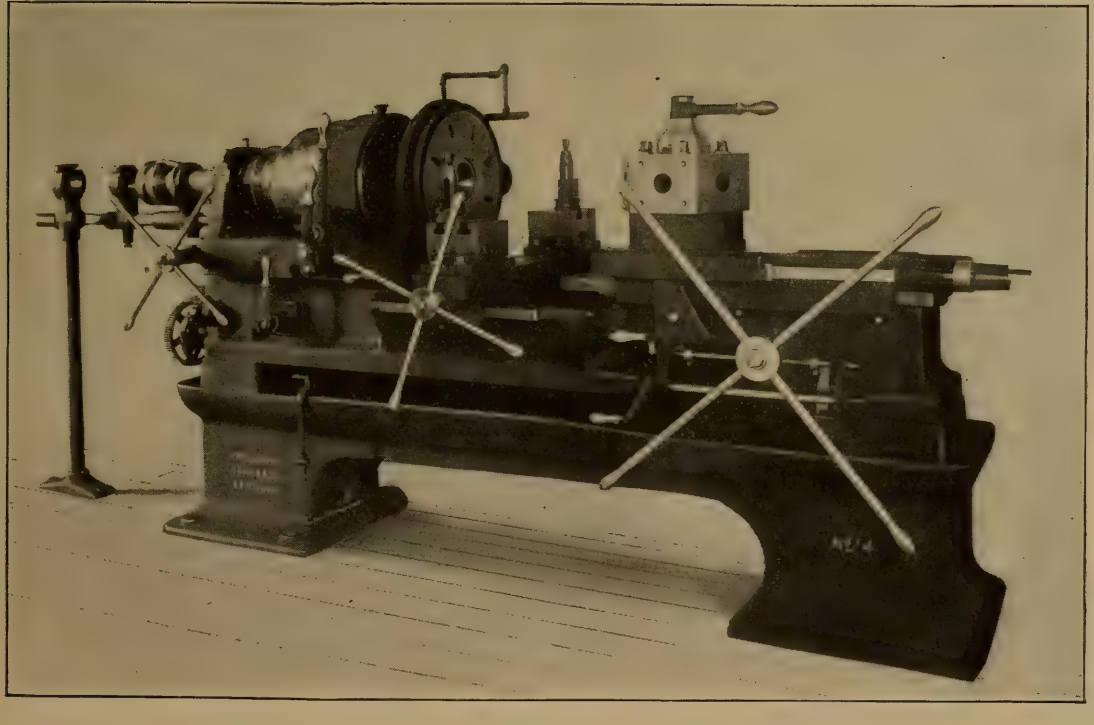


FIG. 15.—SCREW MACHINE BUILT BY THE GARVIN MACHINE CO., NEW YORK

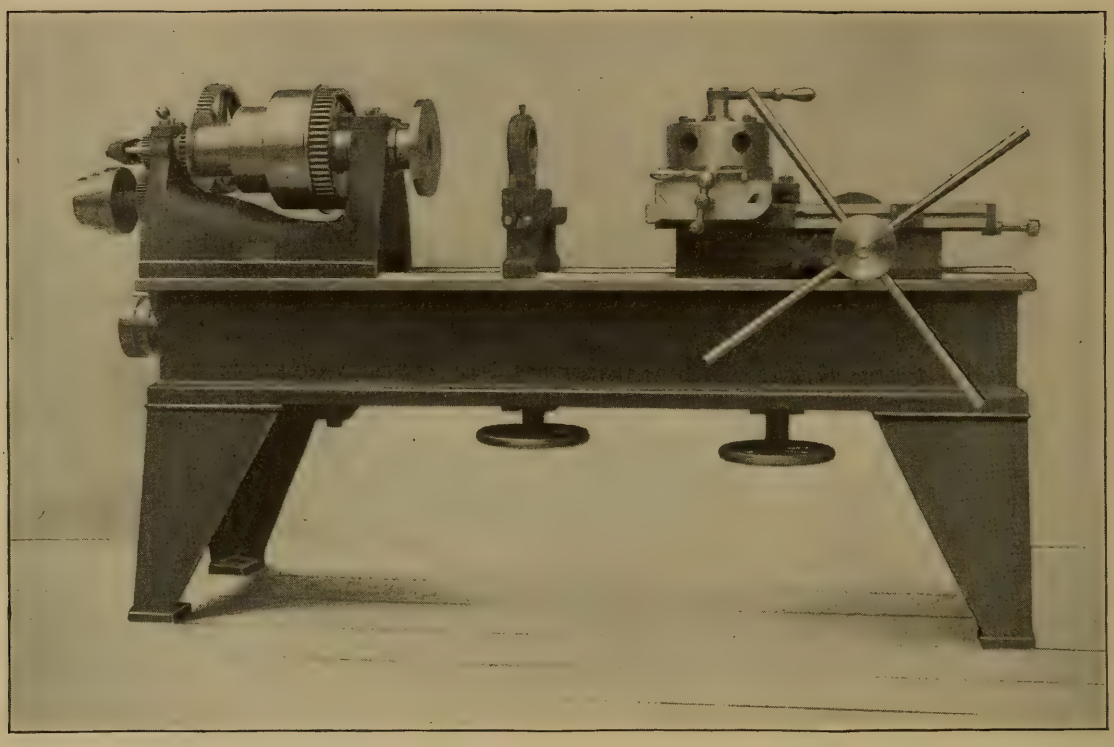


FIG. 16.—CHUCKING LATHE MADE BY THE WM. H. EDDY CO., WORCESTER, MASS.

has a traverse of 24½ inches, and is provided with stop motions.

The machine shown in Fig. 15, made by the Garvin Machine Company, New York City, represents their No. 14 screw machine fitted with wire feed for bar work, and of such dimensions as to render it available for finishing castings and automobile and bicycle parts. The form of bed and base are novel, and the gap for cross slide ways offers an opportunity of increased swing. Fig. 16, finally, represents a chucking lathe made by the William H. Eddy Company, of Worcester, Mass. The general character of the design is well illustrated in the view here given.

Scroll chucks are used with some of the heavier types of lathes shown in the illustrations, and, as a means of facilitating rapid production, have proved very successful. An examination of catalogues of the makers of turret lathes will convince one of the extent and application of such tools, and some idea of the magnitude of the business may be gained. It may be said, in conclusion, that many manufacturers who consider the purchase of turret lathes are reluctant to undertake their use on account of the fact that many special tools may be needed in order to do the work to the best advantage; but the results thus far have nearly always been orders for duplicate machines because of the great saving in time of doing work and the consequent economy.

WASTE HEAT AND BY-PRODUCTS FROM THE BLAST FURNACE

SOME MEANS OF UTILISING THEM

By William Whitwell, President of the Iron and Steel Institute

Unburnt gases are only a few of the wastes in blast furnace working, though they have latterly attracted the largest share of attention. The others, as well, were summed up recently by Mr. Whitwell in his presidential address to the Iron and Steel Institute, and that portion of it dealing with them is given in the following pages.—THE EDITOR.

WASTE HEAT IN BLAST FURNACE WORKING

THERE are two items of waste heat in blast furnace operations which must be self evident to all who have watched the tapping of furnaces, namely, the loss of the heat contained in the iron and the slag. Taking the iron first, the results are as follows:—Heat lost in 100 tons of pig equivalent to 4.125 tons of coal. Thus in a blast furnace plant producing, say, 100,000 tons yearly, the heat lost in the iron will equal 4125 tons of coal. The total make of the Cleveland district approximates 2,225,000 tons yearly, and the heat in this weight of iron will be equal to 92,800 tons of coal. If in all our various manufactures it were possible to use the whole of the pig iron made direct from the blast furnaces in the molten condition, in our foundries, iron works and steel works, the problem of utilising this waste heat would be readily solved. Such a condition of things is not likely to occur for some years to come, and though we do at present use some of these 2,225,000 tons direct for the manufacture of steel, the amount so used is not a very large proportion. All the rest is cast into pigs, and the heat is lost. The problem to be solved, therefore, is how to cast the iron into pigs and utilise its heat also. The method of casting in sand is still by far the most universal one, and most of the iron so cast is judged by fracture as regards quality. Judgment by fracture only is, however, decreasing in importance; the composition as shown by analysis is considered the best guide. Hence casting in sand might be done away with, and some method of casting adopted which would utilise some of the heat now allowed to go to waste.

The heat in the slag is an even more serious item of waste than that in the iron. A furnace working on Cleveland iron stone produces 30 cwt. of slag per ton of pig, or 150 tons of slag to 100 tons of iron. The heat in 150 tons of slag is equivalent to 10.3 tons of coal. Thus in a blast furnace plant producing 100 000 tons of Cleveland pig yearly, the heat lost in the slag will be equivalent to 10,300 tons of coal. The total make of Cleveland pig approximates 1,300,000 tons, carrying with it 1,950,000 tons of slag. Add to this 720,000 tons of slag produced in the manufacture of other kinds of iron, and we get a total of 2,670,000 tons produced yearly in the Cleveland district. The heat in this weight of slag is equal to 183,340 tons of coal, and if we add to this the loss in the iron, the total amounts to 276,140 tons,—over a quarter of a million. At 10 shillings per ton this is equal to £138,070, representing the value of the waste heat in the iron and slag of the Cleveland district. It would, of course, be impossible to recover all this waste heat and apply it to some useful purpose, but a large proportion of it should be reclaimed,—a problem for metallurgists and engineers to solve.

As far as I know, only Sir Lowthian

Bell, in Great Britain, has attempted to utilise the waste heat in the slag. Some years ago he took out two patents, the first being as follows:—The slag ball was run into a bath of water under a salt pan, the steam rising underneath the pan and heating the brine. This was not successful. In the second patent the slag balls were run into a brick-lined chamber, the roof of which was a salt pan, and the exhaust steam from the blast engines was turned into this chamber. When the balls were in, the temperature rose to 500 or 600 degrees Fahr., the steam before going in being about 212 degrees. This was sufficient to evaporate the brine, and for some time salt was manufactured in this way. The brine contained 22 per cent. of salt, the pans were 20 feet square, and forty-four to forty-seven pounds of salt per square foot of pan were made. This also was abandoned owing to the action of the heat on the bogies, as the chamber acted almost like a soaking pit, and also if a ball burst inside, it practically meant cooling down the chamber so that men could go in and clear away the stuff. This naturally meant a stoppage of the pan during the cooling down and clearing of the chamber.

There is one direction in which the heat of the slag might be utilised,—that is, in the drying of wet ores which are used direct in the blast furnace. The ores from Bilbao often contain over 10 per cent. of moisture. Taking the percentage of moisture in the mixture used for the furnace charge at 8 per cent., there will be 3.04 cwt. of water in the 38 cwt. of ore required to make a ton of hematite pig iron. The evaporation of this water will use heat equivalent to 0.407 cwt. of coke as burned in the blast furnace. This means 2.35 tons of coke per 100 tons of pig, or about 18½ tons per furnace per week. If we could dry these ores by the waste heat of the slag, we would not only save coke, but the furnace would work much more freely. When the ores are wet and in a sticky condition a perfect mixing of ore, coke and limestone in charging is not easily attained, the ore remaining in sticky masses, causing irregular working and liability to hanging. Also the gases are so full of steam that they burn very badly, and where a plant is making nothing but hematite pig it is often difficult to keep up full steam pressure without firing the boilers with coal to a small extent.

This question of waste heat is one which touches all departments of iron and steel manufacture, but in blast furnaces alone there is a mine of wealth in waste heat waiting for some one to successfully tap it. The time will come when it will be a problem which will have to be tackled and solved if it is possible to do so.

UTILISATION OF WASTE BY-PRODUCTS

The principal by-products of the blast furnace are gas and slag. The former has for many years been successfully applied for heating stoves for the hot blast and raising steam for the blowing engines, pumps, lifts, etc. Seeing that in a well-appointed plant the waste gases are sufficient to supply all the needs of the working of the furnaces, it would seem at first sight that this waste product is being fully utilised. But the problem of using this gas in gas-engines, and so producing power direct, has of late years engaged the minds of engineers and metallurgists at home and abroad.* Though more experimental work in this direction has been carried on abroad than in Great Britain,—notably by the John Cockerill Company, of Seraing,—it is only fair to mention that Mr. James Riley was one of the first to apply, in a practical, though limited, way, Thwaite's system of utilising the power in the gases at the Wishaw blast furnaces of the Steel Company of Scotland about six years ago. The new system appears to have derived a great impetus by the success of the gas engine which was shown by the Cockerill Company at the Paris Exhibition. In a paper read some time ago before the Iron and Steel Institute, Mr. A. Greiner quoted figures showing a surplus of 2000 horse-power per 100 tons of daily

*It may be interesting, in connection with this, to refer to the articles on this subject which have appeared in this magazine in October, 1898, and in March, 1901.—THE EDITOR.

make of pig iron, which, in order not to be over-sanguine, he reduced to an estimate of 1000 horse-power per 100 tons of pig. In the three furnaces of the Thornaby Iron Works, at Stockton-on-Tees, the figures work out as follows:—

Total gas per hour, 2,628,000 cubic feet. Half of this is used by the hot blast stoves, and about 239,000 cubic feet by the boilers which supply the gantry lift, leaving 1,075,000 cubic feet for raising steam for the blowing engines, pumps and furnace hoist. Taking the requirements of a gas-engine at 130 cubic feet of gas per horse-power per hour, these 1,075,000 cubic feet of gas are capable of producing 8269 horse-power. The horse-power of the blast engines, pumps and furnace hoist engine total 1388, leaving a surplus of 6881. Taking an ordinary day's make at 350 tons, this gives 1900 horse-power per 100 tons in favour of gas-engines. This calculated result comes out very close to the figures quoted by Mr. Greiner, but if to be on the safe side we take his reduced estimate of 1000 horse-power as the surplus, we get a wonderful result when taken over such a district as Cleveland. The make per day approximates 6100 tons, and at 1000 horse-power per 100 tons we have a surplus of 61,000 horse-power, equal to the consumption of more than 500,000 tons of coal per year. The uses that this power might be put to are endless, driving all the machinery in the works, and supplying electric light and power for outside consumption. Though this problem of utilising blast furnace gases is not yet completely solved, I feel certain it very soon will be, and we may see the day when, as has been previously suggested, blast furnaces will be power producers, with the pig iron a by-product.

We can now arrive at an estimate of the waste going on in the blast furnaces of the Cleveland district. Horse-power in the gases, 61,000; waste heat in the iron and slag, equal to 276,140 tons of coal, or 31,500 horse-power; total power going to waste, 92,500 horse-power.

The horse-power of Niagara Falls is estimated at 7,000,000. The amount at present supplied by the Niagara Falls Hydraulic Power & Manufacturing Company is about 50,000. Our waste, then, may be looked on as a small Niagara, which, if we could see it in the form of a waterfall, would very speedily convince us of the enormous amount of energy being lost.

UTILISATION OF SLAG

The total make of slag in the Cleveland district is 2,670,000 tons yearly. Many attempts have been made in the past to turn it to some good purpose, with more or less success; but the accumulation of slag goes on, and great, useless, unsightly heaps are extending in all directions. A stranger from the South of England passing by one of these huge slag hills one rather misty day caught a glimpse of it through the smoke and fog, and thinking it one of the famous Cleveland hills, was anxious to know the name of it. It certainly was a Cleveland "hill," but not such as he was thinking of. Many firms at Middlesbrough, not having tipping ground, have to send the slag out to sea at a cost of over a shilling per ton of iron.

The principal uses of slag at present are as road metal and paving blocks, or scoria blocks, as they are called. It also forms the basis of artificial stone work and concrete flagging, but these consume only a small portion of the total make, and the problem is to succeed in the directions in which others failed in the past, and also, if possible, find other and more extensive means of utilisation.

The setting properties of granulated slag or slag sand, when suitably treated, have long been known. In 1887 J. E. Stead read a paper before the Cleveland Institution of Engineers on "Hydraulic Cement from Cleveland Slag." The process he described consisted in mixing and grinding to an impalpable fine powder 75 per cent. dried slag sand and 25 per cent. slaked dry lime. The powder so produced is slag cement. In strength it compared most favourably with Portland cement, and there seemed

every probability of the process being a success, and an important industry established. The principal element in the success of the cement rests in the extreme fineness to which it is ground, and this proved the main difficulty, as grinding machinery was speedily destroyed by the slag sand. Since then, however, grinding machinery has been very much improved, and there seems no reason why this manufacture should not be taken up again and made a success.

The Skinningrove Iron Company have given us a very practical example of what can be done with slag cement, for their shipping pier is constructed with this material. The important point about this pier is that the cement was made from ordinary slag, without any desulphurising process being adopted, and contrary to the arguments as to the disintegrating effect of the sulphur, in the form of calcium sulphide turning to sulphate, and the speedy destruction of the pier in consequence, it shows today no such signs of decay.

For some years Wilsons, Pease & Co., under the direction of Charles Wood, manufactured at the Cleveland Slag Works, Middlesbrough, bricks from slag for building purposes. Slag sand mixed with selenitic lime was pressed in bricks in a brick press, stacked under wooden sheds to air-harden for seven days, and then in the open air for five to six weeks to further harden, being ready for the market at the end of that time. The selenitic lime was composed of 80 per cent. unslaked lime, 10 per cent. raw gypsum, and 10 per cent. iron oxide, and 6 cwt. of this mixture was used per 1000 bricks. Buildings constructed of these bricks twenty years ago are in a very good state of preservation at the present time, the bricks being both hard and tough. Many thousands were shipped to London. Their price was at that time 12 shillings per 1000, which did not leave much margin for profit; but seeing the present high prices of building materials, there would be a better chance of the manufacture proving remunerative. The appearance of the bricks is somewhat against them, being of a dull gray colour.

Slag sand, ground fine in a mortar mill with 6 per cent. slaked lime, produces an excellent mortar. It sets rather quickly, a disadvantage in one way, as mortar left over the week end is useless on the Monday following. T. Kirk, of the Carlton Iron Company, informs me that for many years he has not used any lime at all for mortar, all for his building operations having been made out of slag. He grinds together a limy slag and a quarter of its weight of old brick rubbish, with a few clinkers. A good pug mill is required, and it is essential that the grinding be done most thoroughly. Sometimes granulated slag is used. This mortar sets rather slowly, but sets very hard. In a town like Middlesbrough, where building operations are always being extensively carried on, mortar could be supplied at a constant and cheap rate.

Slag wool is still manufactured, and the production of scoria blocks is increasing. The latter are now being shipped from Middlesbrough, and if they were better advertised and the sale pushed, a much greater demand would undoubtedly be created, particularly as their value for paving purposes has been so clearly demonstrated in the towns of the Cleveland district.

Blast furnace slag which is sufficiently soluble to become decomposed in the soil has some value as a fertiliser, not only for the lime it contains, but also, probably, for its contents of silica.

But in spite of all these more or less successful attempts at the utilisation of slag, we are practically as far off as ever in getting rid of, usefully, this costly and unwieldy waste product. It has been clearly shown that useful materials can be made from it, and the problem before us is to make their manufacture a success commercially, and at the same time to find out some other means of utilisation which will absorb, if possible, all the slag made.

CYANIDE FROM THE BLAST FURNACE

In Bell's "Principles of the Manufacture of Iron and Steel" analyses of

the fumes at different levels of an 80-foot furnace are given. At a distance of 26½ feet from the tuyeres the fumes contain 89.2 per cent potassium cyanide. The demand for this substance has of late years increased enormously, owing to its extensive use in the gold fields. Attempts are now being made to extract it from blast furnace fumes, by inserting tubes about the boshes, drawing off the fumes, condensing and collecting the potassium cyanide. Should this prove successful, cyanide would become a valuable by-product.

Current Topics

THE most interesting thing in electrical matters during the past few weeks has been the Edison storage battery, which, from all accounts, appears to have gone a great way towards realising what storage battery workers have been aiming at for so long. The advantages of the Edison battery over the modern lead battery were pointed out by Dr. A. E. Kennelly a few weeks ago in a paper before the American Institute of Electrical Engineers, according to which, in practice, the storage energy of the modern lead battery is from 4 to 6 watt-hours per pound of battery. Expressed in another way, a battery weighs from 124.5 to 186.5 pounds per horse-power-hour at its terminals. In the Edison battery the storage energy per unit of mass is given as 14 watt-hours per pound of battery; or, in other words, the weight of the battery per unit of electric energy at its terminals is 53.3 pounds per horse-power-hour. Thus it will be seen that the Edison battery will accomplish the same work as the modern lead battery and will weigh only about one-third as much. The positive element of the new battery is iron, and the negative element a superoxide of nickel, so that we have a nickel-iron cell. The electrolyte is potash,—an aqueous solution containing from 10 to 40, but preferably 20, per cent. of potassium hydroxide.

THE make-up of the battery is thus described by Dr. Kennelly:—The positive and negative plates are mechanically alike, and can scarcely be distinguished by the eye. They differ only in the chemical contents of their pockets. Each plate is formed of a comparatively thin sheet of steel, 0.024 inch in thickness, in which rectangular holes are stamped, so as to leave a grid or frame somewhat resembling a window frame. Each opening or recess is filled

with a pocket or shallow box containing briquettes of the active material. These boxes correspond to the panes of glass in the window-frame analogy. The positive briquettes are made by mixing a finely divided compound of iron, obtained by a special chemical process, with a nearly equal volume of thin flakes of graphite. The graphite does not enter into any of the chemical actions, but assists the conductivity of the briquettes. The graphite is divided into very thin laminæ by a chemical process, and these are passed through sieves or screens so as to leave a size or area of flake that is much larger than the area of the perforation in the steel windows. The mixture is then pressed into briquettes in a mould, under a hydraulic pressure of about two tons per square inch. The briquettes have a surface area of nearly 3 inches by ½ inch on each face. The negative briquettes are made by similarly mixing a fine divided compound of nickel, obtained by special chemical means, with a nearly equal bulk of fine flakes of graphite, and solidifying the mixture in a mould into briquettes of the same size as those just mentioned. In addition to the superior performance and saving in weight claimed for the battery, the fact is of interest that, according to Mr. Edison, it can be made and sold at a price per kilowatt-hour not greater than the prevailing price of lead cells.

THE reference in Mr. Brown's paper on marine steam boiler efficiency, published elsewhere in this issue, to the usefulness of pin projections in heating surfaces, recalls the old and popular impression that a three-legged pot boiled sooner than one without legs; and this, after all, though it has passed as a fable, is practically true, since the legs act the part of heat conductors in the same manner as the pin projections above mentioned. Mr. C. W. Williams, in his book on "The Combustion of Coal," tells that this was tested by having a large pitch pot made with twenty legs instead of three, the bottom being thus furnished with so many projecting conductors, each six inches long. The result was that pitch or water was more rapidly boiled in this than in one of the ordinary kind. The principle of projecting heat conductors was thus shown to be entitled to attention and practically available.

FROM what has been learnt about China in recent years the conclusion lies uppermost that while Chinese engineering has proceeded quite successfully along static lines, it has rested for centuries without much progress in all that involves motion. Thus, while their fixed structures are notable and frequently beautiful, their machines for doing work and moving people and goods are rudely primitive. The curious Chinese wheelbarrow is still a most important factor in land transportation, but what in the United States, for example, is considered very modern "cage construction" for buildings, has been practiced by the Chinese for centuries, and is found all over China. This is one of many interesting observations made by Mr. William Barclay Parsons during a railroad survey in 1898, and recorded in his recent book entitled "An American Engineer in China." Another example of how the Chinese have, by centuries, anticipated some of our modern inventions, is afforded by the system of dividing up the hull of a boat by bulkheads as a protection against leakage, this, with the Chinese, dating back further than the thirteenth century. The number of compartments in the Chinese trading vessels depended upon the number of owners in a vessel. Mr. John H. Morrison, in an article in this magazine several years ago, told that in a large vessel there were sometimes as many as one hundred, each partner shipping his goods in his own compartment which he fitted up to suit himself, and either went in person or sent one of his family to take charge of his property. There is thus some question whether the Chinese bulkhead or compartment system was designed for insuring safety of the vessel, rather than for

commercial convenience; but there is no doubt that the compartment plan existed at that early date, and that the compartments, too, were made substantial and watertight.

SOMEONE a short time ago said of a very competent American mechanic with whom he had come in contact for several years, that he was the laziest man he had ever known; "that he was so lazy and disliked so much to work that when there was anything to be done he would think of some little scheme to do it better and quicker than was possible in the ordinary way, something that would enable him, further, to do the job without much work himself, and that he would hustle around lively to make the scheme do what he planned it should." In these few lines there are summed up, perhaps not altogether correctly, but certainly in a very pointed way, some of those mental peculiarities of the so-called "Yankee" workman that have made him in the eyes of many a model mechanic. Whatever its mainspring, the fact is pretty well established that he is generally more keenly on the lookout for shop "wrinkles" than the workman of any other nationality, and it is these certainly that help to cut down time, hasten processes and make money for all concerned.

EIGHT sets of 8000-H. P. steam-engines will form part of the equipment of the main power station of the Manhattan Railway Company at New York City, and will be decidedly the most powerful stationary steam-engines thus far built anywhere. There will be nothing that will bear comparison with them except the engines of the great trans-Atlantic liners. According to data supplied by the builders, the E. P. Allis Company, of Milwaukee, Wis., each set will be direct-connected to a 5000-kilowatt electric generator, and will consist of a pair of compound engines working upon the same shaft, the high-pressure cylinders being horizontal and the low-pressure cylinders vertical, both high and low-pressure pistons of each end taking hold of the same crank-pin. The high-pressure cylinders will be 44 inches in diameter, and the low-pressure cylinders, 88 inches, giving a volumetric ratio of 4 to 1, with a common stroke of 5 feet. The speed will be 75 revolutions per minute. The engines were designed by Mr. Edwin Reynolds, vice-president of the Allis Company, and will stand somewhat over 38 feet above the floor level. Each set will occupy about 2000 square feet of floor space. Their steam consumption is guaranteed not to exceed 13 pounds per indicated horse-power per hour.

THE most important feature of the tendency of present locomotive practice in the United States appears to be the recognition of what is known as the "Atlantic" type engine, which, by the way, now holds the world's record for sustained speed, running on the Philadelphia & Reading Railroad. An illustration of one of these locomotives also appears on page 231 of this issue. The advantages of the "Atlantic" type, as pointed out recently by Mr. F. W. Dean before the New England Railroad Club, are that the driving wheels are entirely in front of the fire-box, and that the fire-box can thus be made wide. More grate area can be obtained than in the ordinary locomotive without excessive length of fire-box. Great length of fire-box means difficulty in firing. The "Altantic" type not only gives great width of fire-box, but also considerable depth, because there is underneath a small pair of trailing wheels. The trailing wheels serve also to carry the extra weight of the large fire-box and boiler. In this way boiler capacity is very much increased. The tendency in the large locomotives in the last few years has been to increase the heating surface, while the grate area remained constant, but by the use of the "Atlantic" type, the grate of the locomotive is very much extended, and keeps

pace with the heating surface. Very wide fire-boxes were used with eight-wheel, four-coupled, anthracite-burning locomotives, long before the "Atlantic" type of engine was brought out, by extending a shallow fire-box over the rear driving wheels, but large wheels make this design impracticable. It may not be amiss to add here that the first "Atlantic" type locomotive was built by the Baldwin Locomotive Works, of Philadelphia. To-day, however, it is built by various makers under several different names, and is used by all the leading railways in the United States.

WHILE on the subject of locomotives, it may be interesting to recall that what has been brought out within the past year under the name of the Vanderbilt locomotive boiler.—a corrugated furnace design by Mr. Cornelius Vanderbilt, Jr.,—has had various forerunners, the best-known of which probably was the double-furnace boiler of Mr. George S. Strong of sixteen or seventeen years ago. None of these earlier designs, however, seems to have given the same measure of promise as that of the Vanderbilt engine. Recent tests of the latter on the New York Central Railroad, made under the direction of Mr. S. M. Vauclain, superintendent of the Baldwin Locomotive Works, of Philadelphia, in comparison with a sister engine exactly similar in every respect with the exception of the size and shape of the fire-box, showed an economy in fuel reaching practically 10 per cent. Internal examination of one of these boilers developed the fact that no scale of any account had accumulated on the crown sheet or on the side sheets, whereas on the crown sheets of the other locomotives a very thick scale had formed; sediment had settled and had not been washed off. The fire-box of the ordinary engine was but 42 inches wide, and was full length, 10 feet, in round figures, whereas in the fire-box of the Vanderbilt boiler the grate was about 54 inches wide. With so wide a grate there was no need of great length. The fire-doors were rather high, so that a man had no difficulty in looking at his fire and seeing that the fuel was properly distributed. A portion of the economy, therefore, Mr. Vauclain attributed to the absence of scale in the fire-box and to the fact that the grate surface was nearer square, enabling the man to distribute his fuel to better advantage, and also preventing the fireman from carrying too heavy a fire, whereas in the other engines he can carry the fire as he pleases. Where it is possible to carry a light fire and have a free circulation of air through the grates, getting the proper amount admitted, and admitted at the right time and in the right place, the combustion is, of course, far superior to what it is with a fire-box choked with a fuel layer too deep and too thick and improperly distributed.

IF there be one lesson more than another which has been taught by the researches of the last few years, it is the importance of the almost infinitely little. Mr. William H. Maw, in his recent presidential address before the Institution of Mechanical Engineers, pointed out, for example, that our knowledge of the effect of small differences in the composition of metals and alloys, and of variations in modes of manufacture or of treatment, has been materially increased of late years by the employment of microscopic research. Such researches have already added much to our knowledge of the structure of metals and alloys, and there is every prospect that in the future results of even greater value may be obtained by their aid. They most admirably supplement chemical analysis. It is to the microscope, for example, that we must look largely for the solution of many questions connected with annealing and tempering, about which our knowledge is at present of a very unsatisfactory kind. The aid afforded to engineers by the microscope, moreover, is not confined to the examination of materials of construction. It helps us also to a knowledge of the special peculiarities of

materials on which mechanical appliances have to operate, as, for instance, in paper-making, and in the textile industries; and it may also be advantageously used, far more frequently than it is, in studying the effects of wear caused by the friction of rubbing surfaces.

In connection with the article on blast furnace wastes by Mr. William Whitwell, printed elsewhere in this issue, and in which reference is made, among other things, to the use of blast furnace gases for gas-engine operation, it is worth directing attention once more to the difficulty from dust encountered with such gases. In a paper presented at the latest meeting of the Iron and Steel Institute, Mr. Adolph Greiner, of the Cockerill Works, at Seraing, Belgium, where special study has been given to this matter, explained that the degree of pureness of blast furnace gases varies greatly with different works, and this is easily to be understood from the different natures of the ores smelted. Generally speaking, the gases are purer in works producing hematite pig irons from hard ores in lumps, or mixed with purple ores, when, as is the case at Seraing, the dust from these last (always rather heavy) is deposited in the pipes and chambers nearest the blast furnaces, and is not carried any very great distance. On the contrary, the gases contain large quantities of fine dust in works which deal with oolitic ores, whose impurities consist mainly of a kind of clay which the heat causes to dry, and which the gaseous current carries to great distances. It is a mistake to suppose that this dust can be efficiently separated by depositing in long passages, vertical pipe arrangements, or chambers of large capacity. The dust is often reduced to such a state of tenuity that the gas continues to carry it in spite of all checks of the kind referred to, and the clouds of white smoke issuing from the tops of high chimneys prove that the gas after travelling hundreds of yards still contains appreciable masses of light solid matter.

At Differdingen, Luxemburg, where dust of this kind is encountered, a choice had to be made between two methods. The first, which may be termed the "static" method, consists in the use of a series of scrubbers or sheet-iron towers containing coke or sawdust, cooled by a spray of water, which plan, first introduced by Mr. Thwaite, is in use in England, and also in different forms at the Oberhausen blast furnaces in Germany, at Dudelingen, in the Grand Duchy of Luxemburg, and elsewhere. This method is somewhat cumbersome and costly to put down, requiring the use of an aspirating fan or exhauster, but it gives perfect results as regards cleaning. The second method, which might be called the "dynamic" one, is based upon a reaction, due to centrifugal force, produced between the gaseous mixture and a spray of water injected into a suitable apparatus. The liquid and solid particles thrown against the periphery of the apparatus are expelled by an opening in the casing, while the gases, which have been mixed and agitated by the action of rotating blades, escape through an exhaust orifice in a perfectly purified condition.

At Differdingen the principle of the "dynamic" cleansing has been very simply carried out by using an ordinary centrifugal fan, about 5 feet in diameter, running at a speed of 900 revolutions per minute, through which the whole of the gases is passed, being drawn in through the central apertures. Water is supplied through a 1-inch pipe opening into the axial part of the fan. The gas alone is driven out through the fan discharge; the water charged with the dust is led off through a 2-inch pipe from the lower part of the fan casing. The gases, which before being brought into the fan, contained 4 grams of dust per cubic meter, leave it containing only 0.25 gram, and are in a proper condition for use in a gas-engine without further treatment. The quantity of water required is very small, and varies with the degree of cleanliness to be ob-

tained. With 10,000 liters of water per hour the dust in the gas can be reduced to 0.30 gram per cubic meter, and with 15,000 liters to 0.20 gram. The apparatus takes up little room, and is by no means costly. For an outlay of 10,000 francs the gas can be cleaned for six 600-horse-power engines. Mr. Meier, the general manager of the Differdingen Works, intends to carry out the cleansing operations more completely by sending the gases leaving a first fan through a second one; experience can alone decide whether this improvement is necessary. It may be of interest to point out that the "dynamic" method of cleansing possesses the advantage over the ordinary one of supplying the gas at a certain pressure (from 20 to 25 cm. water gauge), by which it becomes possible to carry it in sufficient quantity through pipes of comparatively small diameter, and thus reduce the first cost. It having thus been shown that the cleansing of blast furnace gas can be effected simply and economically, there seems to be no reason why the principle should not be carried further and the gases cleaned before use in hot blast stoves or under boilers.

One of the several important points involved in the matter of electric power transmission for factories is the influence of the newer power upon the general arrangement of the building or buildings, or rather its negative influence, since the design is not dictated or controlled by it, as has always been the case with the older system of long line shafting and its accessories. Professor William S. Aldrich, in a paper read at the recent spring meeting of the American Society of Mechanical Engineers, dealing with the requirements of electricity in manufacturing work, emphasised this feature, pointing out that there is now a superior adaptation of the building to manufacturing work and sanitary requirements, with higher ceilings for light, ventilation, and overhead transportation. The cost of buildings is reduced to a minimum. The electric drive does not require the heavy construction of walls, overhead work, and roof trusses demanded by shafting transmission. The site for buildings may be chosen independent of power considerations and located on most suitable ground. There is no necessity for buildings being placed around, or adjacent to, the power house, as required for mechanical connections to engines or turbines. Grouped shops may be arranged in the best manner to facilitate economic production and the handling, conveying, and transportation of material and work. Detached buildings, a tendency of certain lines of modern manufacturing development, are feasible, and the work in them is facilitated by electric transmission. The isolation of various shops, departments, and workrooms for manufacturing or insurance reasons may, moreover, be carried to any extent with the electric system without impairing its efficiency or economy.

As to workshop expansion, future areas of work may be planned and arranged for with the utmost freedom and entirely irrespective of power considerations. They can be located as desired, on separate floors, in various departments or in detached buildings. Original provision for prospective development is not necessary in the electric system, but is required by shafting transmission. There is no expense for contemplated additions till they are actually installed as required. Permanent additions to the electric generating plant and the distributing system are made with a gradual and *pro rata* outlay of capital, instead of in disproportionate blocks of new equipment, as required by mechanical transmission. Extensions of electric transmission and new centres of power distribution may be established at any time and of reasonable capacity, anywhere and at any distance, at minimum cost for labour and material. There is no crowding, overloading, or interference with existing conditions, or with the daily progress of routine work. Temporary ex-

tensions, to meet sudden demands for power at any point, are quickly made by running electric wires to the desired location. These are easily removed when no longer required, and are as readily used elsewhere for similar purposes. The shafts are made with the least expense of time and labour in handling, and with no accompanying waste of material to suit different conditions. Auxiliary power is always at hand for emergencies, and to almost any reasonable extent, on account of the reserve nature of the electric supply.

LEO DAFT

An Electric Railway Pioneer

A BIOGRAPHICAL SKETCH

AS one of the pioneers in electric railway engineering, Mr. Leo Daft will be remembered by a great many in the electrical profession, and the portrait of him which is printed in this issue will bring back to mind some of the very interesting work done by him in the early eighties at Greenville, New Jersey, where both a small experimental railway and a workshop were driven electrically and with much promise of that success which has been so amply fulfilled since that time.

Mr. Daft was born at Birmingham, England, in November, 1843, his father being Thomas B. Daft, a civil engineer of some prominence, and with his early leaning toward mechanical and electrical pursuits, he entered the London University College engineering class in 1859 as a special student under Dr. William Pole, F. R. S. He came to the United States in 1866, and first engaged in railroad engineering in connection with some extensions of the Louisville & Nashville Railroad, then in course of construction.

On the death of his father, in 1879, he went to England, and upon his return, about two months later, the developing activity in electrical matters recalled him to his old occupation. His first connection was with the New York Electric Light Company, which was soon merged into the Daft Electric Company, with works, first in New York, then at Greenville, N. J., and later at Marion, N. J. The company was almost immediately and exclusively devoted to the development of electric power machinery, and established several electric power stations at Boston, New York, and Worcester.

In 1883 Daft built an electric locomotive named the *Ampere* for use on the Saratoga & Mount McGregor Railroad, and in the following year installed short lines at Coney Island and elsewhere. On August 9, 1883, he put in operation what was probably the first electric elevator in the world, at the Garner Cotton Mills, Newburgh, N. Y. In January, 1884, he supplied the machinery for the New York Power Company's first power distributing station in Gold street, New York, and in May of that year the Massachusetts Electric Power Company was incorporated and fully supplied with electric machinery by the Daft Company. This was the first instance of a complete central station for the electrical distribution of power on a commercial scale, and all the apparatus was manufactured by the Daft Company.

In the early spring of 1885 Daft was requested to furnish an electric equipment for a branch of the lines of the Baltimore Union Passenger Railway Company, and in August, 1885, the Baltimore & Hampden branch was operated with the electric machinery, and

continued in uninterrupted operation for four years without change of rolling stock or station apparatus; and in the light of more recent events it is interesting to note that the four independent motors were of the single-reduction type, towing 16-foot trailers, and the regulation was series-parallel, the four spools of each motor being so connected to the controller without the use of idle resistance in any form. The Daft road at Baltimore was particularly successful in demonstrating, in the face of general opinion to the contrary, that several cars could be worked in parallel from the same line, and that there was ample power for running around curves and mounting heavy grades. The first motor cars were the *Morse* and the *Faraday*, and a third insulated rail was used. The Daft system was used on a number of roads, and the Daft locomotive *Ben Franklin* was operated for some time on the Ninth Avenue Elevated road, New York.

Regarding Mr. Daft's work in the distribution of power to stationary motors by electricity, it may be mentioned that in 1884 the *Electrical World*, desiring to make an exhibit at the Philadelphia Electrical Exhibition, determined to print its issue there by electricity. It was easier, however, to form the plan than to carry it out, but the Daft Company guaranteed a successful performance, and Mr. Daft himself took a hearty interest in the project. The generator motor and press were duly set up, and within the five weeks of the exhibition 80,000 copies of the paper were printed from electrotypes, the type being set in New York. This feat, besides attracting universal attention, gave, at a critical time, a direct and lasting impulse to the electrical motor industry in this country.

As one example of the development of electric power in New York not more than a dozen years ago, it may be stated that in 1889 about 700 horse-power was daily distributed by the Daft system to about 200 consumers in quantities varying from ½ to 30 horse-power. All the apparatus, including motors, generators, switches, meters, etc., was of Mr. Daft's design, and there was probably no other installation of the kind in that respect in the world. In other words, Mr. Daft was the only inventor, up to that time, who had taken up the problem of the distribution of power electrically and worked it out in the same manner as current for lighting, providing and perfecting the necessary apparatus throughout.

Mr. Daft is now engaged as a consulting electrical engineer, besides being retained in special cases by both the General Electric and Westinghouse companies, and is at present residing in England.

PHOTO BY J. RUSSELL & SONS, LONDON

SIR JOHN AIRD, BART., M.P.

CONTRACTOR FOR THE NILE RESERVOIRS

SEE PAGE 343

CASSIER'S MAGAZINE

VOL. XX AUGUST, 1901 No. 4

THE NILE RESERVOIRS

By John Ward, F. S. A., Author of "Pyramids and Progress"

HERODOTOS said of Egypt that "there was no land which possessed so many wonders," and this was 2350 years ago. Yet the Father of History saw the ancient land only in the days of its decline; its greatest architectural and engineering works had been done many thousand years before his time. The story we have to tell to day shows that Egypt is still a land of wonders, and its latest, as an engineering feat, is possibly the greatest of its kind the world has ever seen.

We owe much to Egypt,—our letters, our architecture, our art. The earliest specimen of each of these branches of civilisation is to be found in Egypt. And we are giving a tardy return to the Nile country, we of the west, in planning and executing for it engineering works that promise to be the salvation of its great and famous river, and make it the means of a regeneration of the old land. The earliest Egyptian public work recorded for us was a damming of the Nile. Doubtless when Mena, first King of all Egypt, built his famous "White Wall," diverting the river, it was a dyke to keep up the level of the water, to supply the reclaimed land of the delta, before his time a useless swamp. The seven branches of the Nile had all the aspect of artificial channels, and traces of ancient dykes are everywhere found. Mena lived 4400 B. C. Again, about 2700 B. C., the Amenemhats and Usertesens of the Twelfth Dynasty carried out vast engineering works, by which the Nile was conveyed (by a canal which still exists, the Bahr Yusuf) to the Libyan desert, and thereby added a new province to Egypt. The Nile reservoirs, now under construction, are working out the same problem,—to husband the waters of the High Nile, hitherto lost in the Mediterranean,—for the perennial irrigation of Egypt.

In ancient days there were doubtless natural rocky barriers on the Nile, which acted in restraining the torrent for irrigation purposes. These have, in the course of ages, been worn away completely. Therefore, the works now in progress have to be on a gigantic scale,

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THE ISLAND OF PHILAE, WITH ITS ANCIENT TEMPLES AND MONUMENTS, ALL OF WHICH WILL BE SUBMERGED BY THE DAMMING OF THE NILE AT ASSOUAN

and built of permanent stone and iron, as the volume of water they have to restrain and impound is greater than was required in the olden time. Had the early Egyptians needed to do their works of stone, they were quite competent to hew, transport, and build to perfection, larger masses than we moderns have attempted. Their temples, pyramids, obelisks, and colossi required engineers' talent to detach and erect. Had it been necessary, therefore, they could have built their dykes of stone, but those that remain to us are earthworks, sufficient for their requirements. They must also have had a system of sluices, to regulate the flood, but no drawing of such has as yet been discovered.

WILLIAM WILLCOCKS. M. INST. C. E., SURVEYOR OF THE NILE RESERVOIRS

Before proceeding to describe the gigantic weirs of masonry now under construction, the greatest the world has seen, it may be well to say a few words about the origin of the present scheme. Napoleon gets the credit of having suggested the first barrage of the Nile. This may be true, for he had been trained as an engineer. His great mind may have seen, therefore, that waste of water went on at the period of the river's annual flood. But his time in

Egypt was short, and nothing was done for forty years. Mahomet Ali sent to France for engineers to increase his revenue by scientifically improving the ancient irrigation system, which had been allowed to deteriorate by Turkish neglect. Having the tradition of their great Napoleon's idea of a dam or dyke below Cairo, to store up water for the delta, these engineers suggested various schemes.

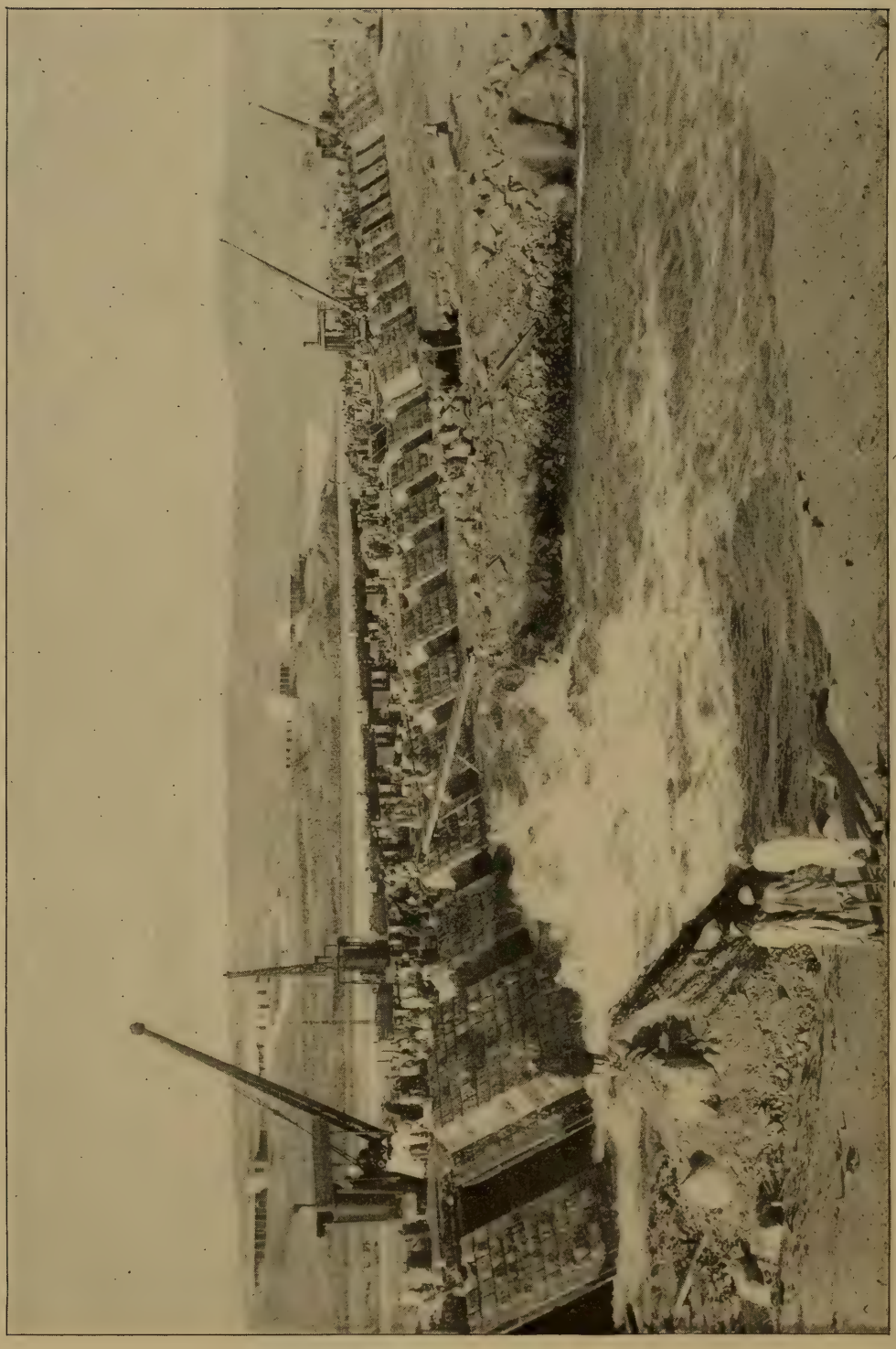
None seemed feasible, till one of them, afterwards known as Mougel Bey, produced a design that found favour in Mahomet Ali's eyes. This was a pretentious structure, a grand, showy building with locks, gates, and drawbridges. It also embraced a great scheme of forts to fortify Cairo against attack from the north, the only quarter from which he feared attack. With characteristic energy, Mahomet ordered the plan to be carried out at once, and thousands of fellaheen were torn from their homes and set to work. It was forced labour; the wretches were unpaid, and often unfed. The tyrant cared not. More than 20,000 of these poor serfs had perished in making his great canal to Alexandria, and why not use the same sort of cheap material? Then when dams of Nile mud, scooped out by their wretched hands, began to rise up, the question was where to get the stone. "Use up those useless heaps of stone, the Pyramids," said Mahomet Ali. Fortunately, the engineer in charge convinced him it would be cheaper to quarry new stone in the Mokattum hills, and so the Pyramids escaped.

The work went on slowly and was not completed when Mahomet Ali died, in 1849. His successor, Ismail, carried it on, and it was reported finished in 1861. But those in charge of the enterprise,—a great staff of highly-paid officials, with costly Frenchmen at their head,—were afraid to fully close the sluices. These were only planks of wood, which had to be lifted by manual labour in or out of the 120 openings, requiring many men to each, should the Nile be rising or falling rapidly.

At last, one day, in 1863, a bold young engineer had all the openings closed. The water rose, and the pressure was so great that the whole wall began to move downstream! The gates were hurriedly opened, and they never tried to fully close them again, only a few feet of water being held up. The staff was kept on, the forts had soldiers to watch the costly toy,—(it is supposed to have cost over a million sterling),—and the public forgot its very existence. Then Ismail's troubles came, and the

State became bankrupt. The rebellion of Arabi Pasha followed, and France and Great Britain sent fleets and troops to Egypt. But the French sailed away from Alexandria, allowing the British to fight out the struggle alone, and this is how Great Britain got control of Egypt.

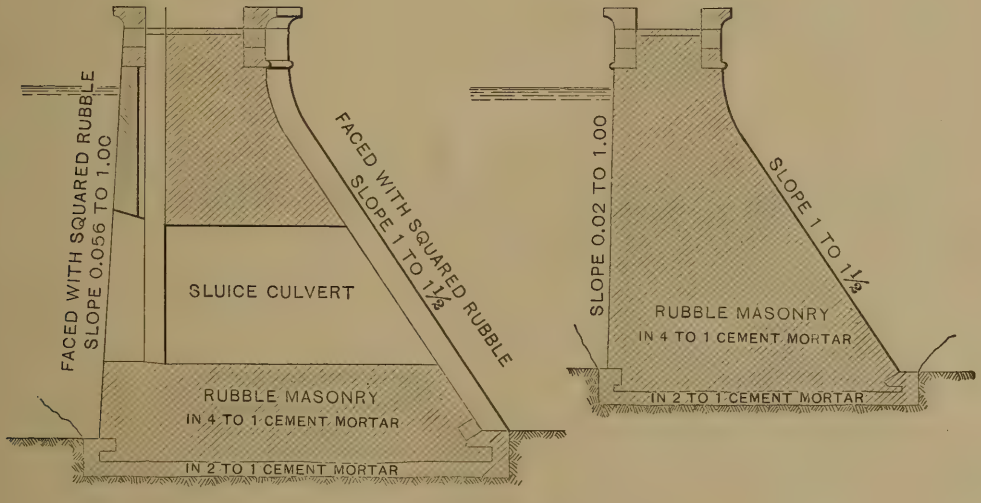
The question now arose, what was she to do with it? Lord Granville had



A GENERAL VIEW OF THE ASSOUAN DAM

all confidence in Lord Dufferin's powers to settle any difficulty whatever. Already, as British ambassador, he had had a difficult task at Constantinople, but had checkmated the Sultan, who would otherwise have sent his fleet to back Arabi and brought about a European war. So Lord Dufferin was asked to visit Egypt and report on the spot, 1882-1883. His masterly despatches have been printed as Blue-books, and are matters of history.

To restore the government Lord Dufferin advised that British officers and British irrigation engineers should be brought from India for the control of the irrigation, on which depended


FACED WITH SQUARED RUBBLE
SLOPE 0.056 TO 1.00
SLUICE CULVERT
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SLOPE 1 TO 1½
RUBBLE MASONRY
IN 4 TO 1 CEMENT MORTAR
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SLOPE 0.02 TO 1.00
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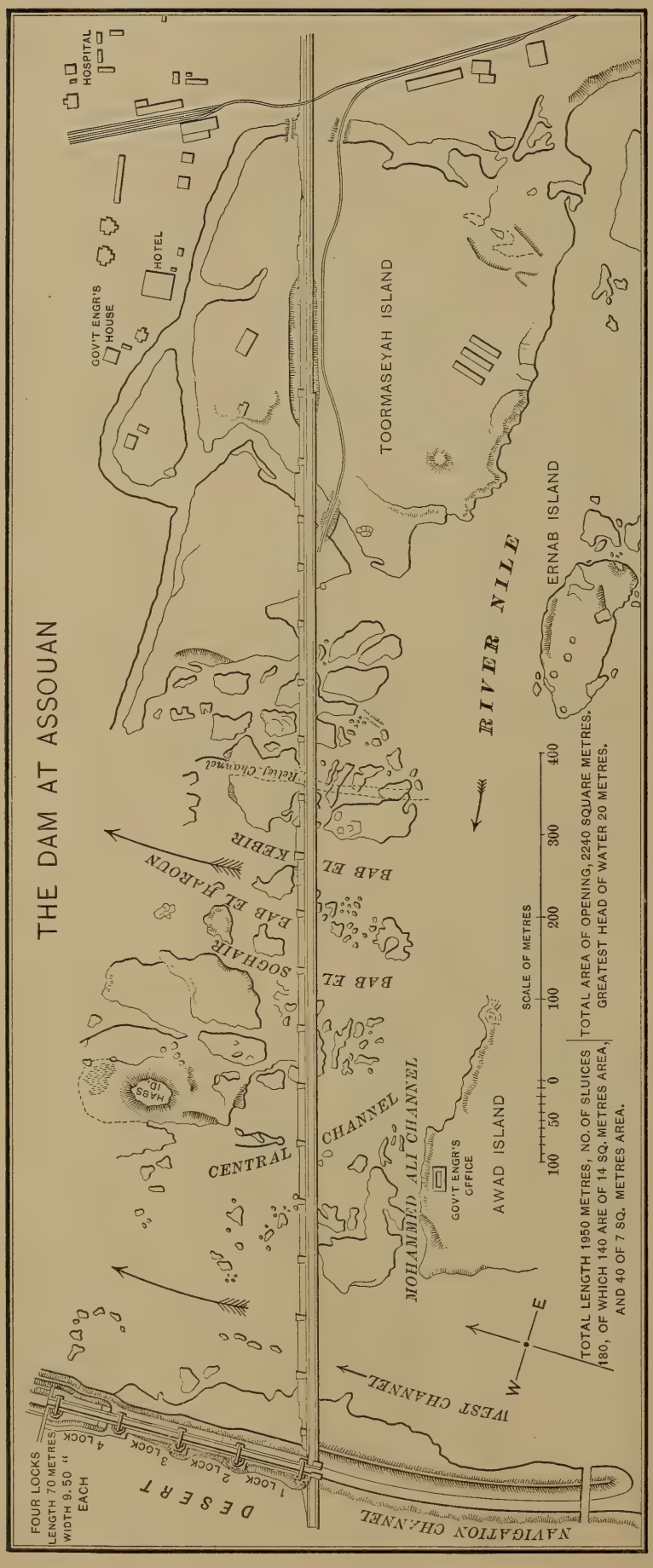
CROSS SECTIONS OF THE DAM

the revenue of the country. This advice was taken, and it saved Egypt. Lord Dufferin resided in Cairo for some time and drew up those wonderful reports on the spot. As Sir Alfred Milner says* of them:—" A series too good to be buried in a Blue book, it is impossible for anyone well acquainted with Egypt to read those despatches without admiration. The writer's mastery of the subject is extraordinary." In fact, Lord Dufferin's advice gave Great Britain the control of Egypt, and that control at once changed the aspect of affairs. The stricken land, nigh unto death, began to revive, and gradually to recover its place among civilised nations. Lord Cromer came and has remained at the helm ever since, giving his life to the work. Sir William Garstin, Major Hanbury Brown, Mr. Willcocks, and others are there still. Some have perished in the struggle, for life in Egypt all the year round is a severe task indeed, and especially so for the exposed life of an engineer. Sir Colin Moncrieff and others have left, having earned well-deserved promotion. As I am talking only of engineers, I do not mention Sir Alfred Milner, Sir Edwin Palmer, and many others of the financial department who helped on the good work; and as for soldiers, I do not mention them at all, though not from a desire to pass over their great services.

Irrigation is the life-blood of the country, and under the Indian system everything began to improve. The new Indian engineers were bound to economise, and, therefore, dismissed the costly officials who were sticking to it like barnacles on a derelict. They examined the structure, and found it had no foundation! No wonder it had cracked and begun a voyage to the Mediterranean when the sluices were closed. Sir John Fowler was consulted and reported against it, advising its entire removal, at an estimated cost of a million sterling. But Sir Colin Scott Moncrieff, who was then in charge, offered to underpin the walls and save the structure, making it do its work, for half a million sterling. The story of

* England in Egypt, by Alfred Milner, 1892.



how it was done is well told in Major Hanbury Brown's "History of the Barrage." The work took three years to do. It has long ago repaid its cost, and the old French barrage, condemned as a useless incumbrance, is now a great source of income, having doubled the agricultural revenue from the delta.

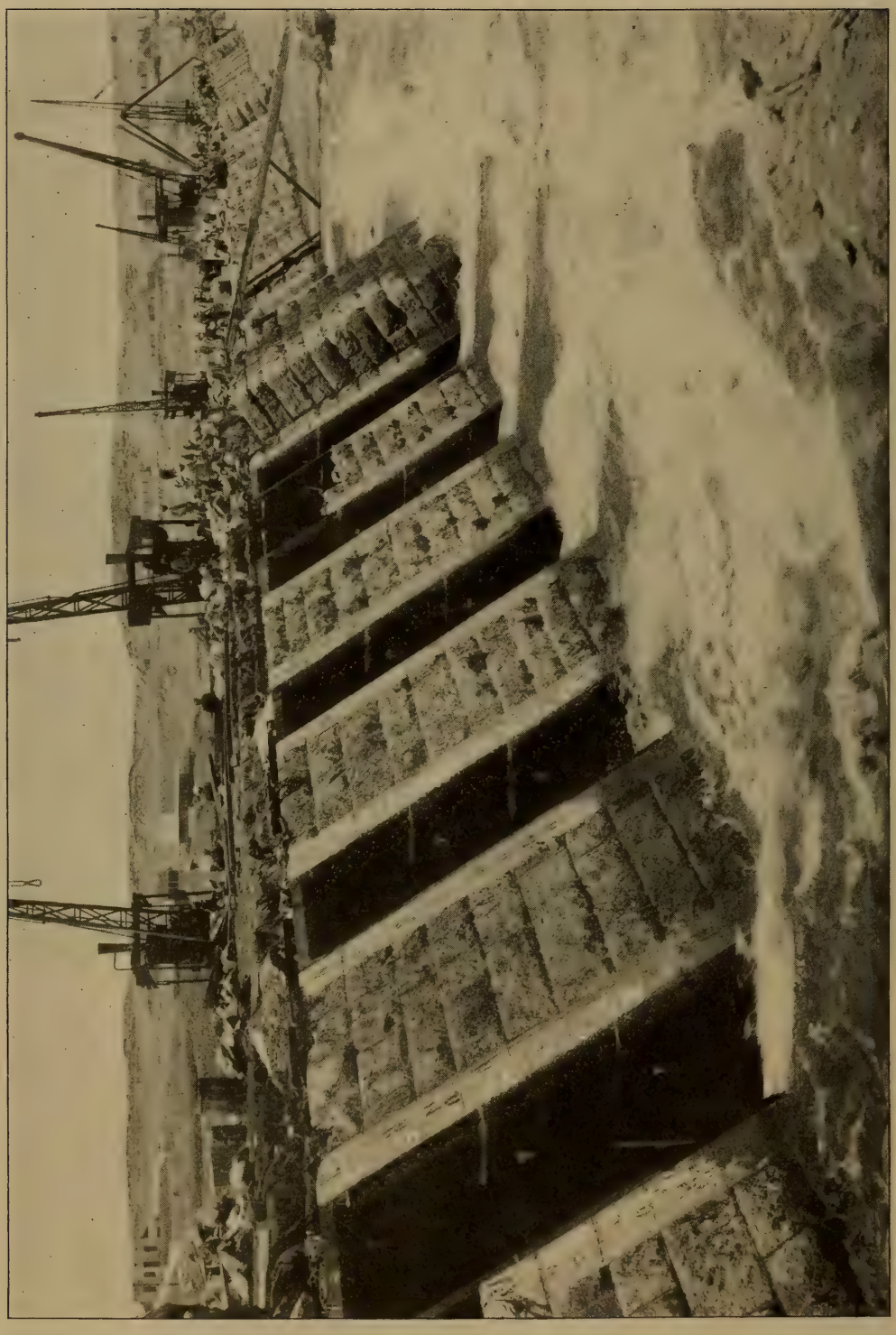
The success in saving the structure, long regarded as useless, gave Sir William Garstin and his staff of engineers a desire to do more good to the thirsty land by extending the work to Upper Egypt. Lord Cromer backed them up with his accustomed energy, and Mr. William Willcocks was asked to report on the whole Nile valley, being given *carte blanche* as to the selection of sites and plans for future reservoirs. He spent three years at this superhuman task, doing almost all the work himself, as to tramping over the country, taking levels, mainly with the help of a sturdy Nubian. A large book of plans, sections, and working drawings was the result. Six or seven schemes were laid before the government, two being specially recommended by Mr. Willcocks in a masterly report on "The Perennial Irrigation of Egypt." Final estimates were obtained. But the cost would amount to several millions sterling, according to Sir Benjamin Baker, now appointed consulting engineer of Egypt, and Egypt had no money. Lord Cromer, therefore,

had to let the plans go back to Sir William Garstin's keeping, and they were comfortably pigeonholed. Lord Cromer told me himself, with regret, that he would never see them carried out in his day But the unexpected always happens! Sir Benjamin Baker had reported on these plans and advised their execution. Some little bird must have told certain capitalists and contractors how matters stood, for Sir John Aird, representing them, one day called on Lord Cromer and his chief engineers and offered to make two barrages, or dams, navigation canals, irrigation channels, and anything else required in a period of five years, and asked for no payment till the work was done. Even then they were willing to defer the settlement, spreading it over thirty years, at the end of which payment would cease. Their terms were accepted. They gave no security, and asked for none, from Great Britain or from Egypt. And so the great works were begun, and will be completed, to all appearance, long before the expiration of the five years.

The work was commenced in 1899 at Assouan, near the "First Cataract," and also at Assiout, 200 miles nearer Cairo, where the "supplemental" dam will be. Within a few months 20,000 men were employed. The scene in 1900 at Assouan, with crowds of willing workers, railways and locomotives, great cranes by hundreds, toiling away under Egypt's blue sky and burning sun, baffles description. The din, the screaming steam-engines, the noise of blasting operations, the babble of confused tongues, Arabic, English, Italian, Greek, French, and of Nubians and Soudanese who talk some unknown lingo, is deafening, even above the roar of what remains of the cataract. Around us is a waste of destroyed granite masses torn to pieces with dynamite. A huge "sadd"* of earth and stones keeps the

BAB-EL-SOGAIR. CUTTING THE TEMPORARY "SADD" DURING THE NILE FLOOD OF 1900

*"Sadd," or "Sudd," is the Arabic word for impediment, a blocking up,—a dam. This term is also applied to the mass of decayed vegetable matter which has been so much heard of as filling up the Nile channel in equatorial regions.



NORTH FACE OF THE DAM AT BAB-EL-KEBIR

Nile from breaking in where the masons work along the line of wall. Huge cranes lift immense blocks of granite, swing them round, and deftly deposit each in its proper bed. Later we see the iron grooved sashes built in the openings where the gates will be placed.

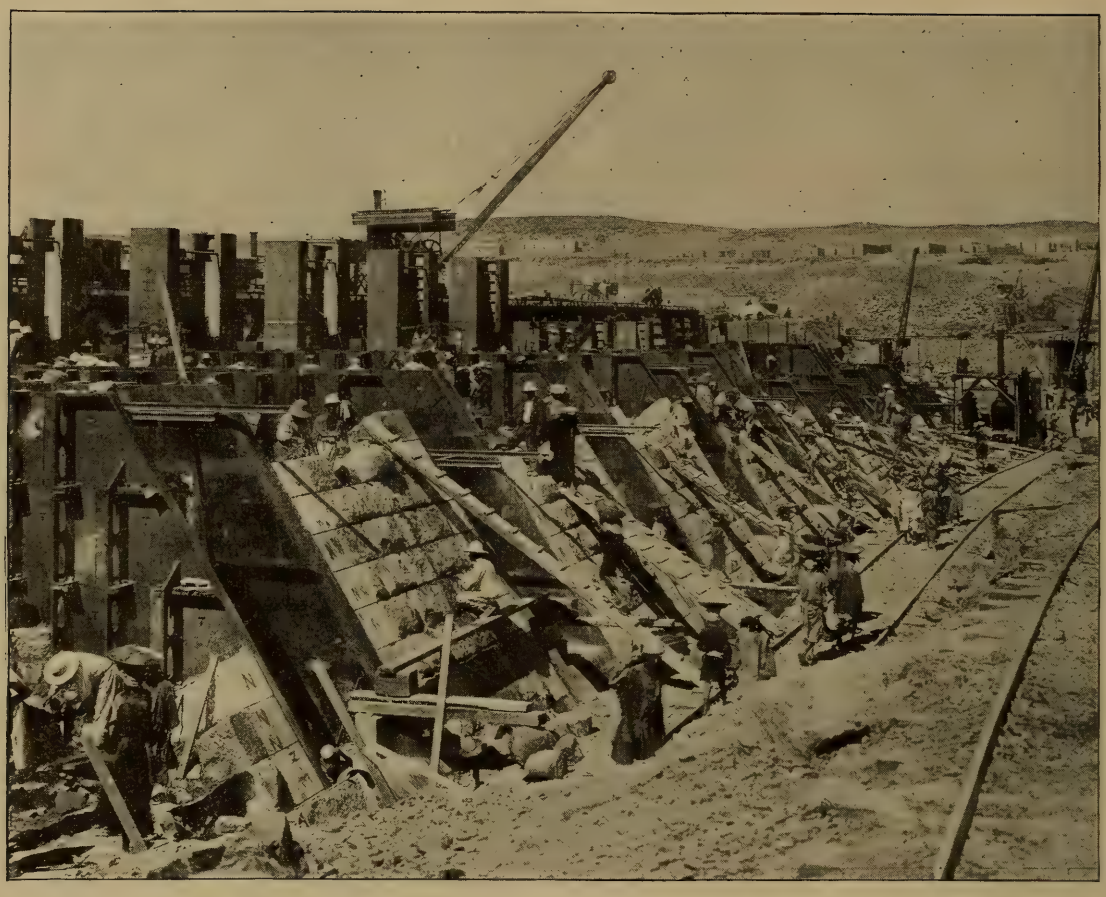
Fantastic granite rocks rise up towards the south, bounding the view, while northwards stretches the sandy desert, enclosed by barren sandstone cliffs. Along the river's edge are groves of date palms. The whole is a very wonderful scene, of indescribable beauty in the distance, with Titanic destruction of every natural feature of the landscape going on in the foreground,—a pandemonium let loose upon a paradise! The crevices and crannies of the rugged granite cliffs which rise beyond the doomed island of Philae are filled with blue shadows of iridescent tints. Their hue and their veins of quartz or silica shine out like crystals or diamonds, as they catch the sun's rays and flash through the shimmering air.

Mr. Willcocks selected this point for several reasons. It is the only place on the Nile where a natural barrier of granite exists. His original plan was to have a wall of granite, right across the narrowest part of the valley, sufficiently high to bank up the river to a height of 120 feet. This would have given an enormous body of water. But when the plans were handed to Sir Benjamin Baker, as consulting engineer, he was told by the Egyptian Government to cut this down to 65 feet. So the works now in hand will have the water-level, in summer, at a height of 65 feet above the present average level of the Nile. The hills on either side approach in this region closer than elsewhere, being about one and one-half miles apart. The great granite wall joins these cliffs and effectually bars the valley across. As the waters rise, they will fill up the Nile valley southwards for over 140 miles, and unfortuately drown out the present fertile strips of land along the banks, and submerge many tombs and ancient temples in Nubia. The wall will be pierced with one hundred and eighty openings (one hundred and forty of about 150 square feet area, and forty of 75 square feet area). The total area of openings will be about 24,000 square feet. Each opening will be served by Stoney's patent sluices. This is an ingenious invention. By merely turning levers the immense steel shutter is easily raised or lowered, and this with the full pressure of the impounded or running water against it.

Two cross-section views of the dam are given on page 271. One is taken at one of the sluiceways where the dam is much heavier than at other points, in order to admit the sluices and their fixings and to allow for the sluice culverts. The foundation there is also carried down deeper in the rock. The heaviest work the contractors have had was getting sound foundations in the centre, where "faults" appeared in the granite, which was found to be, in parts, quite soft or decomposed. These "faults" had to be cut out and replaced with solid granite masonry in cement. This work of replacement was deeper and heavier than had been expected or estimated for, extending down as far as 26 feet below the level allowed for in the drawings. There will be a roadway along the top of the dam. Its total length will be about 6350 feet. It will exceed 150 feet in depth in some places down to the solid rocky platform on which it stands.

On the west side there is being excavated a navigation canal, with four locks. The change in Egyptian trade and communication between north and south by this canal will be extraordinary, and steamers and sailing boats will pass without hindrance between Egypt and Nubia. Formerly craft could be dragged up over the cataracts only at the time of "high" Nile. To take a dahabieh up cost £50, and steamers could not be taken safely at any cost. The huge wall of masonry itself is nearly up to level on the eastern side. The whole work is much further advanced than was calculated upon, and bids fair to be completed considerably before the five years allowed the contractors.

In 1899 one of the most important



BUILDING UP THE IRON WORK FOR THE GATES AT THE MOHAMMED ALI CHANNEL

works carried out, on which future success largely depended, was the closing of three out of five of the deep channels, which traverse the line of the proposed weir, by temporary dams or "sadds." It was necessary to make these temporary dams before the flood came, and to add layers of sandbags after the flood had subsided. The channels selected for being first closed were the "Bab el Kebir" (the great gate), the "Bab el Haroun," and the "Bab el Soghair." The rush of water through these channels at low Nile is tremendous. As the "Babs" (Arabic for "gate") were successively closed, each remaining one became a seething tumult of rushing flood, so that large rocks of from one to four tons were carried away like pebbles by the force of the water.

Temporary stone dams had been made across each of them before the flood came, to a height of about 16 feet below ordinary flood level. Large rocks were first thrown in, then smaller stones to fill up the interstices. Owing to the rush of water before mentioned, the closing of the Bab el Soghair was a work of considerable difficulty. Sir William Garstin tells how Mr. Fitzmaurice, the chief engineer in charge of the works, succeeded in closing it by an ingenious expedient. He lashed together two large railway waggons with masses of stone contained in wire netting. Each mass of stone and wire weighed from two to eight tons, and the whole was bound together with steel wire. Each waggon, with its contents, weighed twenty-five tons. Rails were then laid to the end of the opening, and the two waggons were run bodily into the gap, forming a mass against which it was possible to pile stone. The total quantity of stone used was about 56,000 cubic yards. When the Nile was at its height the "sadd" of the Bab el Haroun gave way, but was finally effectually closed.

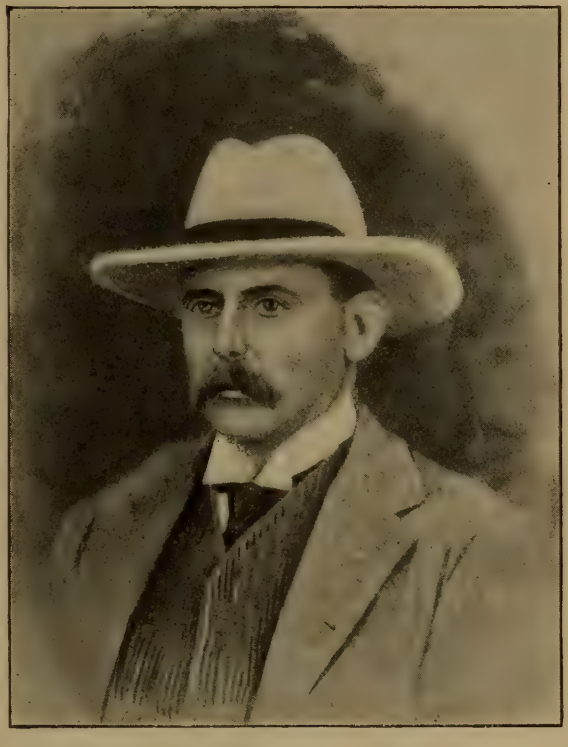
The works have now advanced as far as the western channel, and great progress has been made with the naviga-

tion canal. The photographs tell their own tale of progress more eloquently than words, once the general design of the work is understood.

The Assiout barrage, 200 miles down the Nile, is intended as a subsidiary weir to hold up the water so as to supply the old Ibrahimieh canal, and also new canals at higher level than before. It will thus supply districts not benefited in modern times by irrigation. The Assiout dam is smaller and less pretentious than the one at Assouan, but, like it, deals with the entire river, and will effect quite as great a work in the regeneration of the country. It was originally intended to be made up of brick piers sunk in the Nile, with ashlar masonry between each pier. But it was found that this kind of work was unsuited to the natives whom it was desirable to employ, and the whole plan was, therefore, changed, and with most beneficial results. There is here no rock to build on; the foundation bed is as bad as could be. But from the success in giving a good foundation to the French barrage at Cairo, it was known that, with proper precautions, a reliable substructure could be obtained, even on a bed of sand. The credit of the new work at Assiout is due to Sir Samuel Baker, consulting engineer to the Egyptian Government. Under the supervision of Mr. G. H. Stephens, the resident engineer, the work has proceeded so rapidly that it will probably be completed a year before the date named in the contract.

The site of the dam is about a mile to the northward of the town of Assiout. The foundation is composed of a combined masonry and concrete floor, extending from shore to shore, and laid throughout at the same level. Its breadth is about 85 feet, and it is about 10 feet thick. The upper surface of this floor approximately corresponds to the average river bed level.

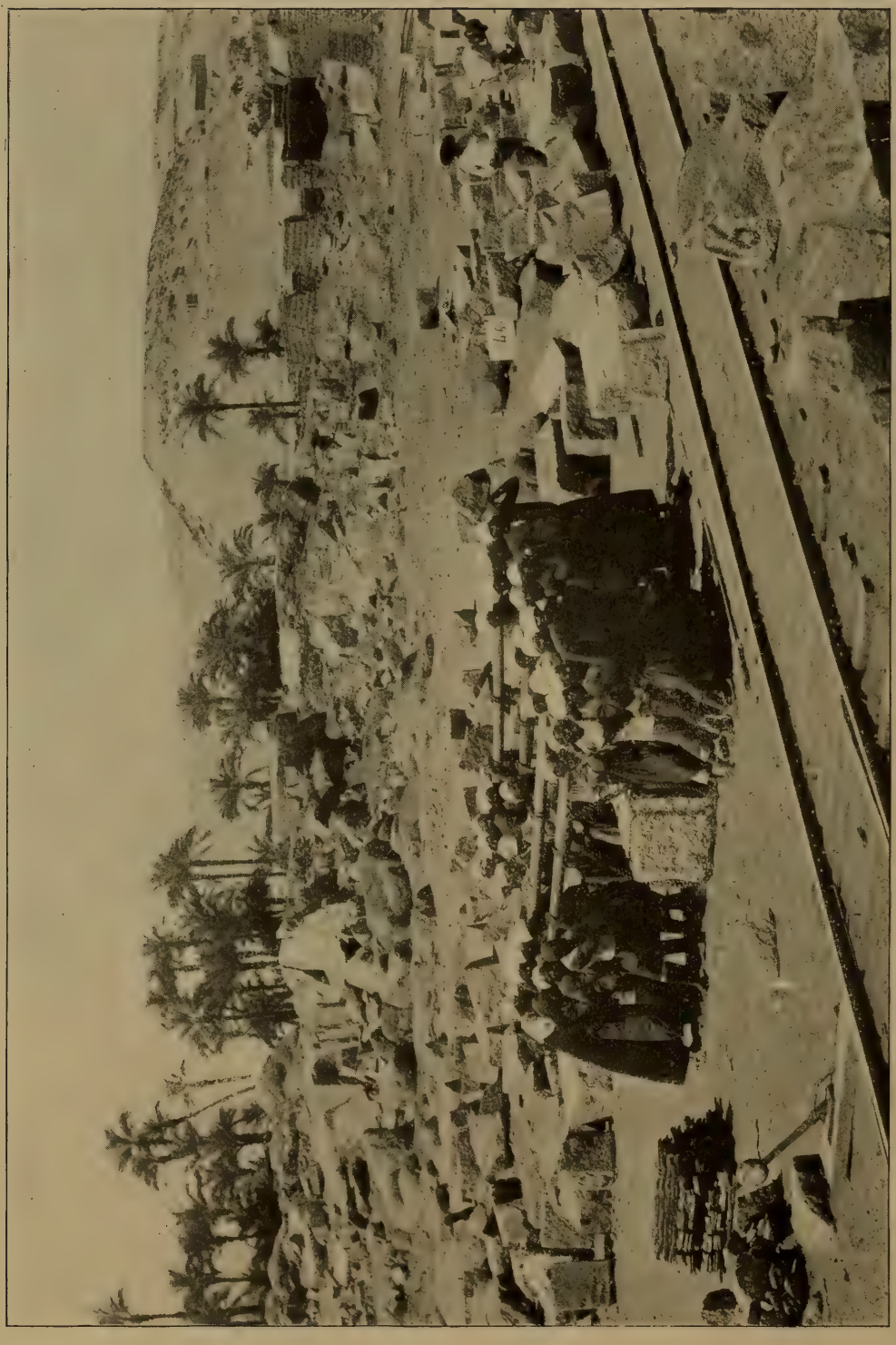
Cast-iron sheet piles, with water-tight joints, were driven to a depth of about 13 feet below the bottom of the floor on both up and downstream sides, and will prevent the percolation of water below the foundation. The superstructure is built upon this floor, and it will, when finished, form a dam somewhat similar in appearance to the old French dam near Cairo. There will be 111 gate openings, and the piers (a total of 110) separating these openings will be spanned by arches, with a roadway about 15 feet in width over the finished structure. With the gates down, the head of water held up during low Nile will be from 10 to 12 feet. A lock 52 feet in width, on the western side, is also provided. The total length of the dam is about 2700 feet, and the height from the top of the



MAURICE FITZMAURICE, M. INST. C. E., RESIDENT ENGINEER AT ASSOUAN

foundation floor to the surface of the roadway is about 41 feet. The stone used is from the Issawieh quarries, near Sohag.

A regulator will be constructed across the head of the Ibrahimieh canal, and will be similar in general design to the dam. It will have nine gate openings, and a lock, about 28 feet in width, will be provided. The Ibrahimieh canal is one of the most important in Egypt. It supplies the Bahr Yusuf, and thus the Nile water is conducted to the Fayum, giving vegetation and the bless-



STONE PORTERS CARRYING A LINTEL STONE WEIGHING 3 TONS. THIS SHOWS HOW POSSIBLY THE ANCIENTS LIFTED SUCH HEAVY WEIGHTS BY MANUAL LABOUR

ings of sweet water to hundreds of villages and many thousands of their inhabitants all along its course. The supply of water will be doubled by the working of this new barrage, leaving enough and to spare for many new canals higher up.

The work done up to the end of 1899 was confined to the western side, and consisted in laying the floor forming the foundation of the lock and the floor under the site of twenty-nine gate openings, or about one-quarter of the length of the dam. The site to be dealt with was surrounded by earthen dams, and the water from the enclosures so made was then pumped out. In addition to the foundation work, the lock walls and the piers for the twenty-nine gate openings were raised to a height above the summer Nile level.

Owing to the low Nile of 1899, an early commencement was made with the preliminary work in 1900. The first work undertaken during the season consisted in constructing temporary dams on the east side of the river enclosing the site of the foundation for fourteen gate openings, equivalent to about one-eighth of the total length of the dam. But the chief work of the season commenced again from the west side, and shortly after the commencement of the above work temporary dams were thrown out from that side, commencing from the end of the previous season's work, and were continued in sections from time to time until by the end of October, 1900, the whole river, from the end of the previous year's work to the Eastern shore, had been enclosed in this way, and the driving of the iron sheet piles was completely finished. The water from the enclosures was pumped out and the foundation was laid for nearly the whole of the remaining length.

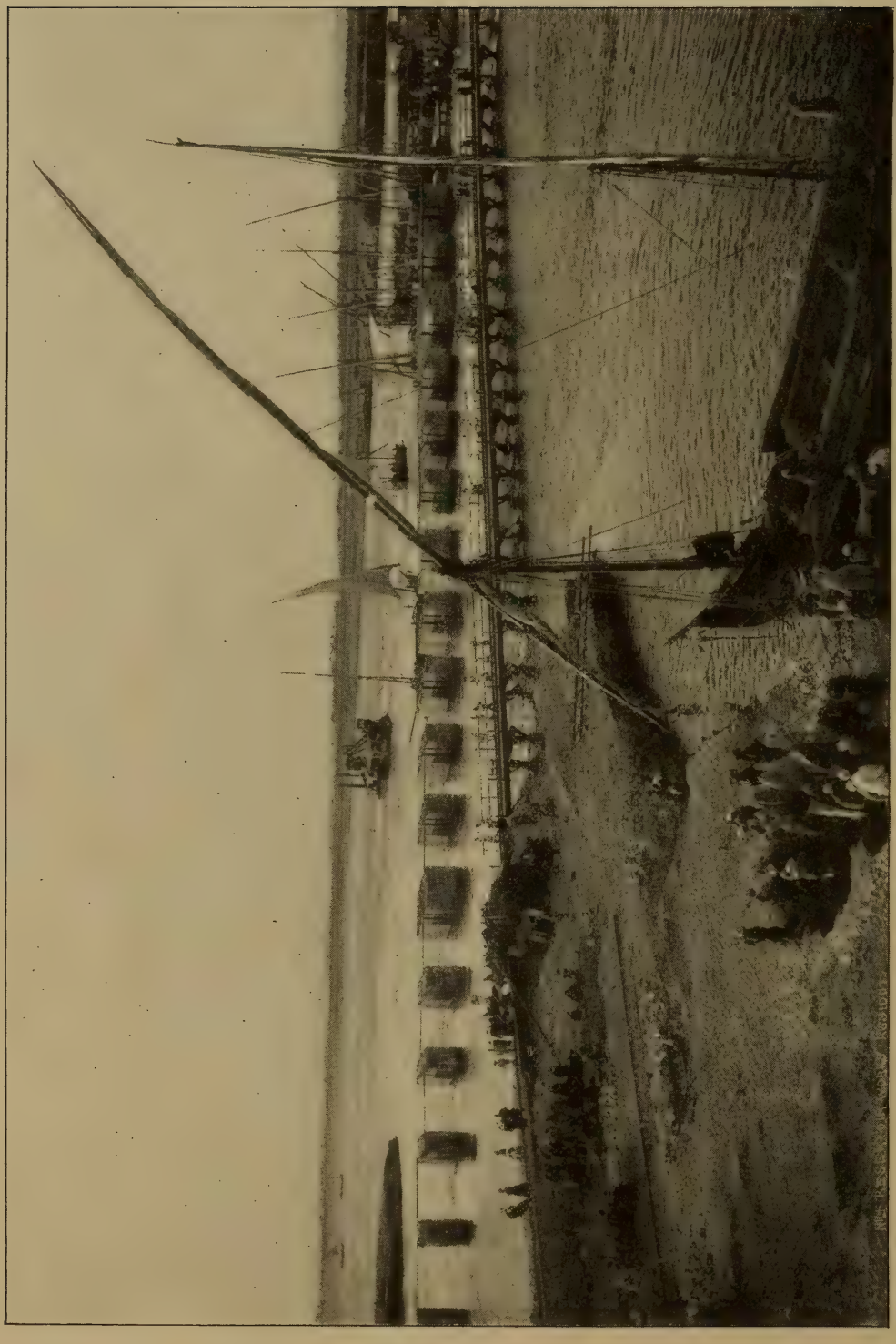
The length of the floor forming the foundation, completely finished during the season, was from the east side over the site of fourteen gate openings, and from the west side over the site of forty-seven gate openings, equivalent to a length of about 1500 feet. The previous season's completed floor extended over the site of the lock and of twenty-nine openings, equivalent to a length of about 780 feet. The piers for the above sixty-one gate openings were also built and were raised above the summer Nile level. The piers and lock walls partly built last season were carried up to the full required height.

The incomplete portion of floor now remaining occupies the site of twenty-one gate openings, but a great part of this floor is nearly finished, the portion left untouched being only a length of about 65 feet.

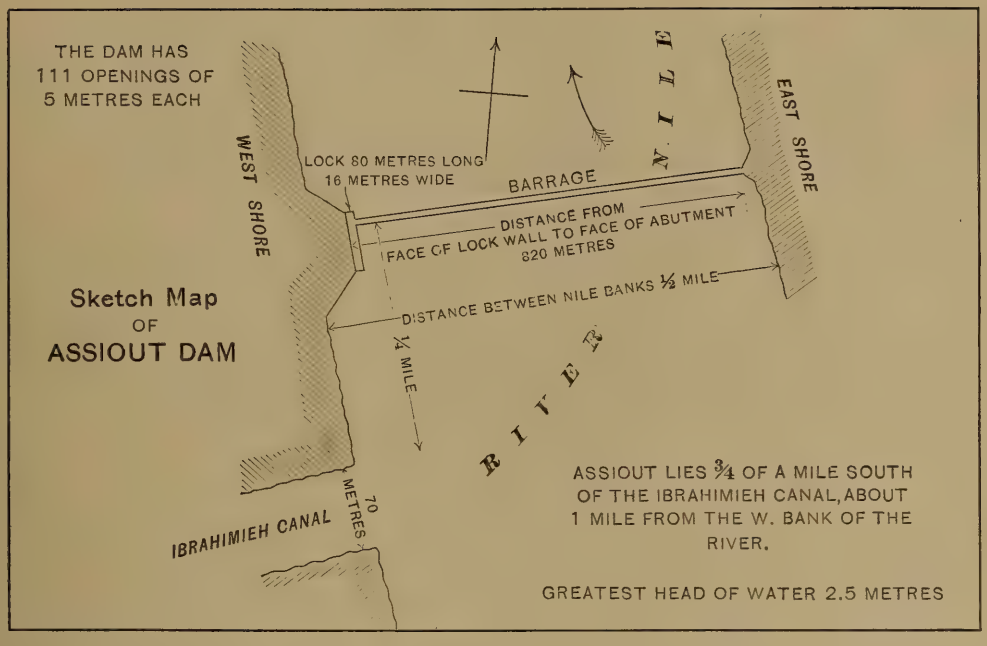
The "high" Nile of the past two years having been unusually low, was most favourable to the progress of the works at Assiout. There was no difficulty in obtaining labour. As many as 10,000 men were employed when the earthwork was being pushed forward.

Since the foregoing was written, after the necessary stoppage during "high" Nile, the work has been resumed with vigour. Such progress has been made that the whole Assiout contract will probably be completed by the end of this year, and the whole subsidiary dam at Assiout can be in use after the flood of next year,—one year before the anticipated time. This can be at once put to do excellent work, even before the great reservoir at Assouan is ready to hold up its thousands of millions of gallons of fertilising Nile water.

There is a strange phenomenon connected with the Nile which has only recently been accounted for. Every ten or eleven years there is what is known as a "low" Nile. The river fails to rise. In 1898, for instance, it could scarcely be said to have risen at all, and was the "worst" Nile ever recorded in modern times. This arose, it is now known, from several causes acting conjointly. The equatorial rains had failed (a similar thing occurs now and then in India), and there had been several successive dry seasons This led to an unusual accumulation of decayed, floating vegetable matter in the various affluents of the Nile under or near the equator. The fierce sun developed vegetable growth in masses of peaty matter. Several great water



THE BEGINNINGS OF THE DAM AT ASSIOUT



courses became choked, and the rivers spread out over level lands, causing vast morasses in which the Nile's feeders were dissipated and much of the waters lost.

The main channels still acted, but were narrowed and impeded by floating islands of vegetable matter. This the natives of that district call "sadd,"—the same word used in Egypt for any obstruction to the river. These impediments often become attached to the river banks, and in some cases extend clear across the waterway, forming bridges of from 5 to 16 feet thick, with running water underneath. These ultimately become so dense that a hippopotamus could walk across them. The news of this state of affairs has been gradually coming to Egypt since the Soudan was conquered.

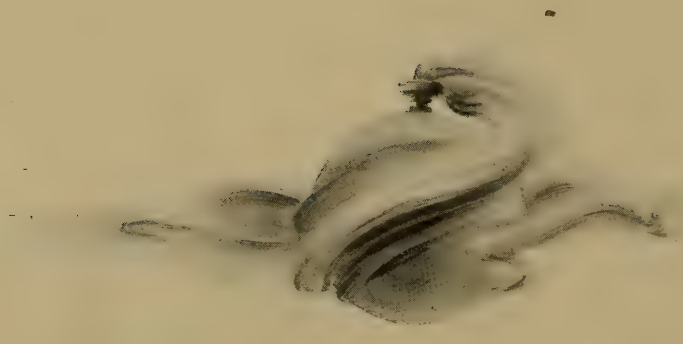
When the low condition of the Nile became alarming, Sir William Garstin sent Major Peake and a detachment of men on the scene to open up a channel for the water, with gunboats, by driving the vessels through the "sadd" after it had been cut. Sir William Garstin visited these regions several times, as is his wont, to inspect operations. The expedition began work two years ago, and has had the effect of successfully freeing a great part of the Nile's course in those far-away regions. Only twenty-one miles of "sadd" remain to be cut, and these can easily be removed next season. The Nile floods in 1899 and 1900, though better than those of 1898, were not up to the average of "good" Niles.

However, the rains promise well now, and doubtless this year will show that Old Hapi (as the Egyptians call the Nile-god) will resume his usual good behaviour and give lots of liquid to the

G. H. STEPHENS, M. INST. C. E., RESIDENT ENGINEER AT ASSIOUT

thirsty land. No doubt the "famine in the land" of Joseph's days, and other famines recorded on Egypt's storied rocks, were similarly caused by failure of equatorial rains. In such times the people died from starvation by thousands. In 1898-99, under the control of Major Brown and his irrigation officers, responsible for the water supply, not one single life was lost from this cause in all the land of Egypt. Rents were remitted to the fellaheen, and grain was given them where needed for food or for next year's crops. Superhuman efforts were made, by deepening canals and making embankments, to husband water all over the country.

"Thank God," one of those noble fellows said to me, "we have saved the country from an impending calamity, and no one has suffered hunger or want over the whole length and breadth of the land." This is the sort of men that Great Britain sends to regenerate Egypt.



UTILISING THE SUN'S ENERGY

By Robert H. Thurston, LL.D., Dr. Eng., Director of Sibley College, Cornell University

MEN of science, familiar with the resources of our globe in the domain of power production and utilisation, and especially all who have considered the origin, extent, and rate of extinction of the quantities of energy available for the purposes of civilised humanity, have, for many years, concerned themselves seriously with the question, "When and how shall we reach and pass the critical period at which the stores of now available latent energy of fossil fuel shall have become exhausted?"

While this problem is not immediately pressing, it cannot be long, time being gauged by the periods of the historian, —it is still more limited in the view of the geologist,—before our stock of coal will be so far depleted as to make serious trouble in our whole social system. Professor Leslie, when State geologist of Pennsylvania, and the late Mr. Eckley B. Cox estimated the probable life of the coal supplies of that State, at the present rate of consumption and acceleration, to be something like a century, and the close of the twentieth century will be very likely to see an end of such manufactures in that State as depend upon cheap fuel and proximity to the coal deposits. In Great Britain the case is probably vastly more serious than in the United States, for there the coal beds are far more restricted in area, and in many localities are already extensively depleted, with prices rising as a consequence. The same is to be said, in perhaps somewhat less degree, of the fuels of the Continent of Europe, and France, and particularly Germany, may ere long feel the effect of a stringency in the fuel market.

Enormous deposits of coal remain untouched in other sections of the globe, and China can probably supply the world for many years; but a time must come, and that within a few generations at most, when some other energy than that of combustion of fuel must be relied upon to do a fair share of the work of the civilised world, and this will probably by that time mean the whole of the world.

Water power, which is the next most important source of energy in manufactures, will do much for us, and that will last as long as humanity survives on this globe; but it is doubtful whether it can be considered as a possible complete substitute for steam power. Yet the total available water power of the world will greatly ameliorate the difficulties likely to arise from extinction of fuel supplies. The mean annual rainfall of the world is 36 inches a year, and this means about 50,000,000 cubic feet per square mile per annum falling on the land of both hemispheres. Taking the mean available height of fall as 10 feet, and assuming it possible to store the water effectively in ample reservoirs, this would mean $500,000,000 \times 60 = 30,000,000,000$ foot-pounds of available energy, and, if expended in three thousand working hours, it would give a total of 10,000,000 horse power per square mile for such countries as might be able to utilise such a fall. This, however, is but a small fraction of the inhabited area of the globe. As a fair estimate, the data for the Mississippi River, in the United States, may be taken. This stream drains about 1,250,000 square miles, with a rainfall of 30 inches, an average, for each foot of fall,

of 11,000,000,000,000 foot-pounds per annum. The fall is 6 inches per mile, average, and the energy capable of use for that area is about a quarter of a million horse-power per square mile.

These figures are enormous, and give the impression that we need not feel uneasy about our power supply, even though we entirely extinguish our fuel deposits. They are, however, of little value; for they give no idea of the practically available energy of rainfall, since it is not possible to make use of more than a minute fraction of this total, and it is not at all probable that we ever can. In the whole length of the Mississippi River there are but three available water powers, one with 78 feet fall at Minneapolis, one with 24 feet at Des Moines, and one with 22 feet at Rock Island. Taking the average flow as a half million cubic feet per second, utilised, the water powers at these points would be a total of about 7,000,000 horse-power, derived from an area of a million and a quarter square miles, and directly from but a fraction of that area, situated above the lowest fall.

The deduction must evidently be that water power alone cannot be depended upon to provide the energy that will be needed by future generations should fuel be unavailable, although it is equally obvious that streams are likely to provide immense quantities of power, and that manufactures, in those coming days, will group themselves about the mill sites or within distances from them which can be spanned by the electric high-tension wire. Of this process of displacement of manufactures, Niagara and Buffalo are already giving impressive illustrations. As time goes on the part to be taken in power production by waterfalls will become increasingly important. It is already vastly greater and more important economically than is generally supposed. There are known water powers in the United States, able to furnish, if fully utilised, something like 200,000,000 horse-power; Niagara, at the falls alone, can supply between four and five millions and a considerable additional quantity from the rapids, above and below the falls, and numerous other water powers distributed over the hilly and mountainous portions of the country will, in time, no doubt, become centres of power production and distribution. The one threatening aspect of the hydraulic power problem is the extreme probability that the continued destruction of forests and vegetation will make the streams more and more unreliable for continuous supply.

Wind power is another source of available energy, like water-power, deriving its origin from the energy of the sun's rays, which may, as time goes on, provide a continually larger amount of utilisable energy for the use of mankind; but it is subject, even in greater degree than water power, to the objection that it is variable and unreliable for steady work. The winds are continually rising and falling. "As variable as the winds" well indicates the uncertainty of atmospheric currents as a source of power for industrial purposes. Rising to a gale and falling to a calm, alternately, the portion of the time during which this power is actually available is small, and still worse, its available periods are as likely to come at unsuitable hours and seasons as when wanted. There is ample wind power for all purposes, undoubtedly, could it be regulated, stored, and economically availed of; but, while no one can say what may or may not be accomplished by the coming inventor, mechanic, and engineer, it does not seem likely that this particular problem will be successfully solved, even under the stimulus of vanishing fuel supplies.

Tidal power is still another possible source of industrial energy, and one which also has its own and peculiar difficulties of utilisation. It is a regular and well-measured and well-known quantity; its hours of rise and fall, and the heights of rise and fall, are well-established; but when it is sought to design a system of utilisation that shall be cheap, practicable, reliable, and compact, one that may compete with other power systems, it is found to be a very difficult, and, for the time, at

least, impracticable, system of power production.

At the moment, engineers and men of science are studying the art of reducing to harness the direct rays of the sun, and the solar engine is exciting special interest. It is no novelty, and many inventors have, for years past, worked upon this attractive problem; but probably at no time in the past has this matter assumed importance to so many thoughtful and intelligent men or excited so much general interest. John Ericsson, the great inventor and mechanic, when writing, in 1876, the great quarto volume which he intended should be the memorial of his life's work, devoted a very large proportion of its space to the account of his solar engines and of the scientific investigations made in the course of his work for the purpose of ascertaining the amount of power thus derivable from the direct rays of the sun. His apparatus was simple,—merely a conical mirror or reflector, receiving the heat of the sun on as large an area as was desired and was found practicable, and directing it to a focus where was placed a steam boiler or an air cylinder within which the fluid, heated to a high temperature, became available for use in a steam or an air-engine. He reported the results of his experiments thus*:—

"It has already been stated that the result of repeated experiments with the concentration apparatus shows that it abstracts on an average, during nine hours a day, for all latitudes between the equator and 45 deg., fully 3.5 units of heat per minute for each square foot of area presented perpendicularly to the sun's rays. Theoretically, this indicates the development of an energy equal to 8.2 horse-power for an area of 100 square feet. On grounds before explained, our calculations of the capabilities of sun power to actuate machinery will, however, be based on one horse-power developed for 100 square feet exposed to solar radiation. The isolated districts of the earth's surface suffering from an excess of solar heat being very numerous, our space only admits of a glance at the sunburnt continents.

"There is a rainless region extending from the northwest coast of Africa to Mongolia, 9000 miles in length and nearly 1000 miles wide. Besides the North African deserts, this region includes the southern coast of the Mediterranean, east of the Gulf of Cabes, Upper Egypt, the eastern and part of the western coast of the Red Sea, part of Syria, the eastern part of the countries watered by the Euphrates and Tigris, Eastern Arabia, the greater part of Persia, the extreme western part of China, Thibet, and, lastly, Mongolia. In the western hemisphere, Lower California, the tableland of Mexico and Guatemala, and the west coast of South America, for a distance of more than 2000 miles, suffer from continuous intense radiant heat.

"Computations of the solar energy wasted on the vast areas thus specified would present an inconceivably great amount of dynamic force. Let us, therefore, merely estimate the mechanical power that would result from utilising the solar heat on a strip of land a single mile in width, along the rainless western coast of America; the southern coast of the Mediterranean, before alluded to; both sides of the alluvial plain of the Nile in Upper Egypt; both sides of the Euphrates and Tigris for a distance of 400 miles above the Persian Gulf; and, finally, a strip, one mile wide, along the rainless portions of the shores of the Red Sea, before pointed out. The aggregate length of these strips of land, selected on account of being accessible by water communication, far exceeds 8000 miles. Adopting the stated length and a width of one mile as a basis of computation, it will be seen that this very narrow belt covers 223,000 millions of square feet. Dividing the latter amount by the area of 100 square feet necessary to produce one horse-power, we learn that 22,300,000 solar engines, each of 100 horse-power, could be kept in constant operation, nine hours a day, by utilising

*Contributions to the Centennial Exhibition, by John Ericsson, 1876. D. Van Nostrand, New York.

only that heat which is now wasted on the assumed small fraction of land extending along some of the water-fronts of the sunburnt regions of the earth.

"Due consideration cannot fail to convince us that the rapid exhaustion of the European coal fields will soon cause great changes with reference to international relations in favour of those countries which are in possession of continuous sun power. Upper Egypt, for instance, will, in the course of a few centuries, derive signal advantage and attain a high political position on account of her perpetual sunshine and the consequent command of unlimited motive force. The time will come when Europe must stop her mills for want of coal. Upper Egypt, then, with her never-ceasing sun power, will invite the European manufacturer to remove his machinery and erect his mills on the firm ground along the sides of the alluvial plain of the Nile, where an amount of motive power may be obtained many times greater than that now employed by all the manufactories of Europe."

The probable value of the quantity of energy transmitted to the earth from the sun, according to the conclusion, after extended investigation, of the late Professor DeVolson Wood, the greatest of American thermodynamists of the nineteenth century, is not far from that obtained by Langley,—133 foot-pounds per square foot of receiving area per second, about $133/550 = 0.24$ horse-power, or the equivalent of 4 square feet per horse-power.* As actually utilised, Ericsson reported his solar engine to supply a horse power from 100 square feet of receiving area, on a bright, clear day, and other experimentalists, with apparently less efficient apparatus, report a horse-power from about 150 square feet in sunshine.

This figure is confirmed by recent experiments at Pasadena, Cal., where it is said that the efficiency reached by Ericsson has in some cases been attained. The California apparatus includes a truncated conical mirror, 33 feet 6 inches in diameter at the top and 15 feet at the bottom, which concentrates the rays of the sun received upon its 1788 facets at a focus where a boiler is placed, and where steam is made, to operate a steam-engine of small power. The whole mass of glass and iron composing the mirror is moved by a suitably arranged clock, and is automatically held with its axis directed toward the sun. The boiler is carried on the same frame and moves with the mirror. It is 13 feet 6 inches in length, and contains about 10 cubic feet of water and 8 cubic feet of steam space. The steam pressure is carried at 150 pounds per square inch. It is rated at ten horse-power. This power is utilised in pumping water, but the reported figures are inconsistent with its rating. To set the machine in operation it is only necessary to turn the apparatus by hand until its axis points at the sun's disk and to set the clockwork in operation. To stop it, requires simply the turning of the mirror away from the sun and the stopping of the machinery which adjusts it.

The uncertainty which the engineer feels regarding this type of motor is due largely to the difficulties arising from the fact that the sun is not always available, even by day, and that it is entirely out of reach for power purposes for one-half the twenty-four hours, and he has as yet no idea of practical methods of storage, either of the heat or the power, for use during cloudy periods, hours, days, and weeks even, when the engine cannot be kept in steady operation. It is, of course, possible that much improvement may be effected in the electric storage battery, and it is even true that great improvements in that precious device are apparently already in sight; but even the ideal and perfect battery, could it be realised, would probably prove so costly and so enormous, as a part of this system of sun-power utilisation, as to make its use practically out of the question in temperate regions where the sky is overcast so often that not over one-half the direct heat of the

* Wood employs this value in his classic and remarkable paper "On the Luminiferous Ether," the first rational determination of the physical properties of the ether, and a most important and impressive work. Phil. Trans. Magazine, November, 1885. App. to Wood's Thermodynamics; N. Y., 1887. J. Wiley & Sons.

sun is each day, on the average, available, or in the tropics where the rainy season makes it unavailable for months together. Where, as may occasionally be practicable, storage may be effected by raising water into extensive and elevated reservoirs provided by Nature, this difficulty may prove less serious; but such exceptional advantages of location cannot be relied upon for any important aid in securing general utilisation of the solar motor.

For necessarily continuous use of power, it is thus evident, this system gives little promise, and a cotton mill, for example, that must go into operation only when the sun comes out from behind a cloud and go out of action the instant it disappears again, can hardly be expected to pay dividends. Water power must be its reliance when coal cannot be employed, rather than either sun power or wind power, and its work must be done where a sufficient amount of fall and flow can be had to meet its maximum requirements, even at the period of minimum flow.

The availability of sunlight and heat for the purposes of the engineer differs greatly in different places, and with every change of latitude, as well as from season to season. This variability is an enormous handicap where it is sought to employ this energy. The remark is attributed to Professor Langley that all the coal deposits of Pennsylvania, if burned in a single second, would not liberate a thousandth part as much heat as does the surface of the sun in that unit of time. Yet it is evident that our coal deposits, so long as they last, are worth more to us than all the available heat of the sun.

In conclusion, we may thus make the following deductions:—

The rapid and rapidly increasing destruction of our stores of mineral fuel must, sooner or later, bring us to a point at which it will be no longer possible to derive the power required, in the arts, from that source.

That period is likely to be ushered in before many generations, and is, in fact, in some portions of the world already presenting its preliminary symptoms,—difficulty in mining and increased price of the fuel in the market as well as the expressed anxiety of statesmen guarding the interests of the great manufacturing districts of Europe.

The ultimate outcome must be the gradual extinction of our fuel supplies, and if no substitute can be devised by the ingenuity of man, the compulsory retreat of the civilised races into the tropics, and, even there, the interruption of the manufacturing industries on the scale necessary to the maintenance of civilised life as we know it to-day.

While it may be true, as has recently been estimated, that the belt extending thirty degrees on either side of the equator may be capable of sustaining a population of ten thousand millions, over ten times the number now inhabiting that portion of the globe, such a population will require correspondingly increased power supplies, if it is to be a civilised population as we to-day define the word.

The available sources of power remaining are wind and water power, and the utilisation of the energy of the direct rays of the sun. The last, though apparently most universally available, has hitherto been unused, while the indirect systems of employment of the sun's energy have been very extensively employed, the deduction being that the former process presents elements of peculiar difficulty.

Water power is, to date, the most available, and the common substitute for the heat-engine. When the existing waterfalls are generally utilised, they will go far toward meeting the needs of the race in power production, and the coincident use of the electric current for the distribution of energy from its source is now making this element of the problem far more promising of solution than previously. Yet it is doubtful whether water power will suffice for all the requirements of later generations, even though the usual result of stimulated brain work, checking of the growth of population, should hold down the numbers of the human race to something like those of the present time.

Wind power, although even more generally distributed than water power, is subject to its own peculiar disadvantages for our purposes, and, while likely to come more and more into use for purposes like that of raising water to higher levels, and where steadiness and continuity of action are not important, will probably be found in great part unavailable for large powers or for the great majority of uses which commonly demand steadiness of power and action.

Solar motors make available an immense quantity of active energy by direct utilisation. They are evidently practicable in the sense that there is no inherent mechanical difficulty in their construction and operation. They are subject, however, to the same defects of lack of steadiness of source of energy, of need for provision for extensive and prolonged storage, if to be generally employed, and to the serious objection of large cost per unit of power delivered. Whether this cost will be so great as to balance the gain coming of free delivery to the machine of the energy to be transformed can be known only when we are driven to the serious task of providing substitutes for the heat engines.

Ericsson made a working steam-engine deriving its energy from the direct rays of the sun, and proved that either steam or air could be employed in such an engine as the working fluid. He also showed what is the amount of power practically derivable from the sun's rays through this method of utilisation of the heat of the sun.

Later testimony, so far as it goes, confirms his statements, and the mechanical possibility is beyond question that, in future centuries, when our fuels are gone, we may largely utilise the sun's energy in this manner. But it may yet be found that this threatened exhaustion of our fuel supplies is not the only, or perhaps even the first, limit likely to be set to the progress of the world of humanity on our globe. The exhaustion of our iron ores, like our platinum deposits, the mingling with the air of the products of combustion of our fuels while they still last, the pollution of our water supplies, and many other possible obstacles to progress and growth, will have their effects, individual and combined, and our most serious problems are quite likely to be found at an earlier date than that of the loss of our fuels; the last-named danger is, in fact, already upon us. This generation need not attempt to cross the first of the bridges on the list, although a very seductive problem is presented to the engineer. This problem may be enunciated thus:—

To find a system of gathering and storing the energy of the direct rays of the sun, for utilisation in power production, by a special form of heat-motor; to find, next, a method of transforming the energy thus collected into mechanical power; and to discover a method of storing, for later use, excess power obtained during periods of sunshine, tiding over the sunless periods.

The problem will be solved only when the system thus perfected is so designed and constructed as to be able to provide power for industrial purposes so cheaply that a business profit can be made through its use.

COMMERCIAL EDUCATION FOR ENGINEERS

By L. S. Randolph, Mem. Am. Soc. C. E.

THE celebrated toast to pure mathematics, "May she never be of any use to anybody," can, with no very great stretch of imagination, be applied to other subjects deemed necessary in the ordinary classical course of study. While of use to some, in a large majority of cases their mission is accomplished, as far as the usefulness of the knowledge is concerned, when the coveted diploma has been conferred. As an eminent Englishman is said to have remarked, "Every boy should study Latin and Greek. It is such a comfort, when one is grown, to say one has forgotten them."

While classical and scientific systems, like the kings of old, were piling up vast pyramids of information, triumphal arches of data and palaces of fact, there arose the idea among some that these building stones could be used for other purposes than perpetuating the memory of some forgotten king or royal potentate. While it may have been sacrilegious to use the sarcophagus of a king for a watering-trough, or the stones of a pyramid for the walls of a dwelling, yet the health and comfort of both man and beast were certainly vastly benefited and the world was much better for such use.

The law of universal gravitation and the law of Ohm, the discoveries of Rankine and of Harvey were great, indeed, but of little more worth than the stones of a pyramid until there arose one whose duty it was to use them. For the training of this man technical schools exist, and for his best equipment much money is spent annually. To him we give the name of engineer. How, then, shall we train him, and what shall he be taught? We may train him in three ways. We may cram his brain with a mass of scientific facts and trust to luck for his using them; no further effort is needed along this ine. We may teach him those facts which he will need, or will be most likely to need, and again trust to luck for his knowing how to use them; or we may teach him the facts and teach him also how to use them. That the latter method is the best will hardly admit of discussion. Of little service is the plane to the carpenter who does not know how to use it; of little use is the most superb machine to the man who does not know how to employ it.

Granting, then, that facts should be taught and that the embryo engineer should be taught to use them, let us consider how and to what extent this line of teaching should be carried. We may say that the young engineer should be taught how to use the facts he has learned. But what, exactly, do we

mean by this? Shall he be taught to partially use them, or completely? Shall he be taught how to determine the size of a belt to transmit a given amount of power at a given speed, and nothing to be said of the proper speed to be used? Or of the effect on the durability of the belt of different stresses? Should we go through the elaborate deductions of the catenary without telling the student that the cables of the suspension bridge more nearly approximate the hyperbola, but do not fit, exactly, either curve?

That these principles are fully realised by many technical schools is unquestionably true, but should we stop even here? In an article on this subject, which appeared several years ago in this magazine, the writer said that the value of the engineer was measured by a money standard. Not only does he still hold to that opinion, but subsequent study and observation have more than ever convinced him of the truth of this declaration. If, then, the work of the engineer is measured by a money unit, is it not wise that he himself be taught to measure his work by this most important unit? We teach him to measure small distance to the forty-thousandth of an inch; we teach him to measure distances of hundreds of miles to the fraction of an inch; we teach him to weigh to the ten-thousandth of a pound, and yet fail to teach him to use the unit of measure by which alone the world measures him and his work, and upon the results of which measurements his reputation and rewards are based.

Doubt may be raised as to the correctness of the statement that the work of the engineer is measured by a money unit. Let us, therefore, examine this point somewhat more at length! The early engineers built bridges which were considered wonderful if they did not fall down; the first locomotives were considered wonderful if they ran at all. At that time the bare fact of the structure performing the work for which it was intended was the only result demanded. Let us try to imagine how long the locomotive designer would stand to-day who simply turned out a locomotive that would run: or a bridge engineer who would build a bridge whose only good point was that it would carry the load! No clearer proof of the proposition could well be furnished than the results of the competition between British and American bridge works for the Atbara bridge contract in Africa, so much spoken of at the time, several years ago, and a more recent one for a railway viaduct in India. In the former the American-built bridge cost one-third less than the proposed British structure, and was erected in a little over half the time; in the latter case the cost was 43 per cent. less, and the work was erected in one-third the time. When we remember that time is money, we can see that in these cases, at least, the sole measure of the capacity of the different engineers was money. It may be urged that this was a business proposition and not an engineering one; that it was due to executive ability and not to engineering skill; but, when we consider that about one-half of the engineering fraternity are in executive positions, and that every detail of the work, from the mining of the ore to the final testing of the bridge, was in the hands of engineers, this argument falls to the ground.

Let us consider, then, how and along what lines instruction should be given. As the measure is the relative number of dollars or pounds required to do the work, it is manifest that the first step would be the methods of determining cost. The writer, upon taking charge of a machine shop, had to close out a contract about completed. On inquiring how a charge of 20 per cent. for uncharged labour was obtained, he was told that it was estimated. It took but a short time to foot up the total charged labour on the previous month's pay-roll, and dividing this into the difference between the total pay-roll and the charged labour, gave the uncharged labour as 47 per cent. As 10 per cent. profit had been charged, the net loss was in the neighbourhood of 17 per cent. on the contract price. It came out later that on $100,000 worth of con-

tracts it took "close bookkeeping" to show $5000 profit. The loss was about $22,000, but the books never showed it. How many manufacturing concerns have gone to the wall by such very "close bookkeeping" no one will ever know.

Business concerns, from the most modest shop to the largest railway and steamship companies, have gone into the hands of receivers from either the entire absence of, or improperly handled, depreciation account. Streaks of rust, rotten ties, scrap heaps of locomotives carried as surplus or capital, have ruined more than one railway. Likewise, spoiled canned goods, moth-eaten clothing and out-of-date goods, carried as assets, cause the ruin of the smaller shopkeeper. The proprietor of the modern department store sells goods slightly out of date for what he can get for them, knowing full well that every day he holds them cuts down their value. It may be urged that these are mere commercial details, incident only to the management of a plant and not to the original design; and yet the success of such a plant as a commercial venture (and that is what it is built for) is directly dependent, in many cases, upon just such considerations. More than one electric plant has gone under because the rapid improvement in electrical equipment was not foreseen and allowed for by a high rate of depreciation.

That the subject of depreciation is an intricate one can be readily shown by asking any given set of men what rate of depreciation should be allowed on a dynamo. One large steel works not long since built an enormous steam hammer. Three years later it was standing idle, being thrown out by the hydraulic press; depreciation, 33 per cent., the usual allowance being 3 per cent. Machines which ten years ago were the best on the market are superseded by those which will permit a competitor to double his output with half the labour; the result is that the new machines must be purchased or the business abandoned. The whole list of the various elements of cost can be gone over in the same way and with the same result.

Profit is the difference between the cost of production and the selling price. In order that there may be profits, it is imperative that the cost of production be accurately ascertained. Not only should the methods of determining the production be carefully and thoroughly taught, but also the methods of lessening the cost. It may seem to be a strong statement, but the writer is thoroughly convinced that commercial considerations have more influence in the design of machinery, certainly, than any other one consideration, and in many cases more than all others combined.

An engineer was asked upon one occasion how he calculated the size of a water main? The reply was, that he could buy four, six, and eight-inch pipe. He knew that four-inch pipe was too small, and he could not afford eight-inch, so that six-inch was all that was left.

An examination of the details of a marine engine and an ordinary stationary engine show careful design and elaborate patterns, on one hand, and the utmost simplicity on the other. The saving of weight pays in the marine engine, but does not in the stationary engine, unless a very large number were to be made.

An elaborate casting for a locomotive was designed upon one occasion. An estimate of the cost of the patterns revealed the fact that the saving of weight on twenty locomotives, over a simple design, would just about pay the extra cost of the patterns. As the order was for only two locomotives, the simpler design was adopted.

Again, each detail of the design must be considered not only in the light of the cost of the material, but of the cost of the shop processes. The engineer designing a machine to be erected in a shop thoroughly equipped with modern machinery can attempt things that he would not dare in a shop equipped with old or antiquated appliances. No more valuable rule can be formulated than this, "that for economical production the design and the constructing ma-

chinery must be fitted, the one to the other, with the utmost care."

The designer must first see that the requisite strength exists, after which every detail of the design is governed by considerations of the cheapness of construction. Often has brass at sixteen to twenty cents per pound been economically substituted for cast iron at two cents per pound, on account of the saving on machine work.

Such instances could be multiplied indefinitely, and they have been brought in here to show how important, if not all-important, commercial considerations are to the designer, and, in consequence, how important this part of the commercial education is to the engineer.

When we come to consider the engineer in executive positions, it seems almost superfluous to discuss it. The day has long gone when the manager of a plant could carry the details of his business in his head; he must have an accounting system which tells him infallibly when the cost has been exceeded, and enable him to go back promptly and certainly and discover the cause.

The commercial education of the engineer should cover two distinct lines:—

First.—He should be thoroughly grounded in the methods of accounting, with special reference to the methods in vogue in manufacturing establishments.

Second.—Through all of his course there should be kept constantly before him and eternally hammered into him the effect of the commercial unit on everything he does, and not only what is the cheapest, but how to determine it.

When engineering graduates are educated in this way we shall have fewer complaints of the impracticable, theoretical man.

THE MACHINERY OF TORPEDO BOATS

By Walter M. McFarland, Late Chief Engineer U. S. N.

WHILE all kinds of steam machinery must of necessity have many points in common, the specific work which any kind has to do and its location have a great effect upon certain details. Machinery for naval vessels resembles that for merchant steamers in many ways, but one of the marked distinctions between the two classes has for the last twenty years been the necessity for reducing weights to the lowest practicable limit in the naval vessel. In such vessels the great demand upon the total weight for many other important purposes leaves the weight available for machinery much less than in the merchant ship.

If this be true for naval vessels generally, it is so in a very marked degree for torpedo boats, where everything else is sacrificed to speed, and where every effort is given to getting the utmost possible result in the shape of power from every pound of weight given to the machinery. Indeed, the comparison with the different arms of the land forces which likens the battleship to the heavy artillery, the ordinary cruisers to the infantry, and the torpedo boats to the cavalry, gives us a very clear idea of the function of these little vessels; or we may take the comparison one degree further and say that, whereas the battleships may be likened to steady-going coach horses and the cruisers to fast roadsters, the torpedo-boats are like

H. M. S. "HAVOCK." THE FIRST TORPEDO BOAT DESTROYER EVER BUILT. COMPLETED IN 1893 BY MESSRS. YARROW & CO., LTD, LONDON, EQUIPPED WITH TWO LOCOMOTIVE BOILERS, MAXIMUM SPEED, 26 KNOTS

H. M TURBINE-DRIVEN TORPEDO BOAT DESTROYER "VIPER." THE FASTEST VESSEL AFLOAT. BEST SPEED RECORD 37 KNOTS

race horses. Sometimes, indeed, and quite accurately, torpedo boats have been described as "racing machines."

Owing to the fact that in torpedo vessels everything is sacrificed to securing high speed, the machinery of these vessels has enabled a great deal of experimental work to be done upon a large scale, and the way has thus been opened for important improvements in the machinery of large ships. The relatively low cost of these little vessels has made governments willing to go to the expense of thus trying on a working scale experiments which they would have felt altogether too costly when applied to

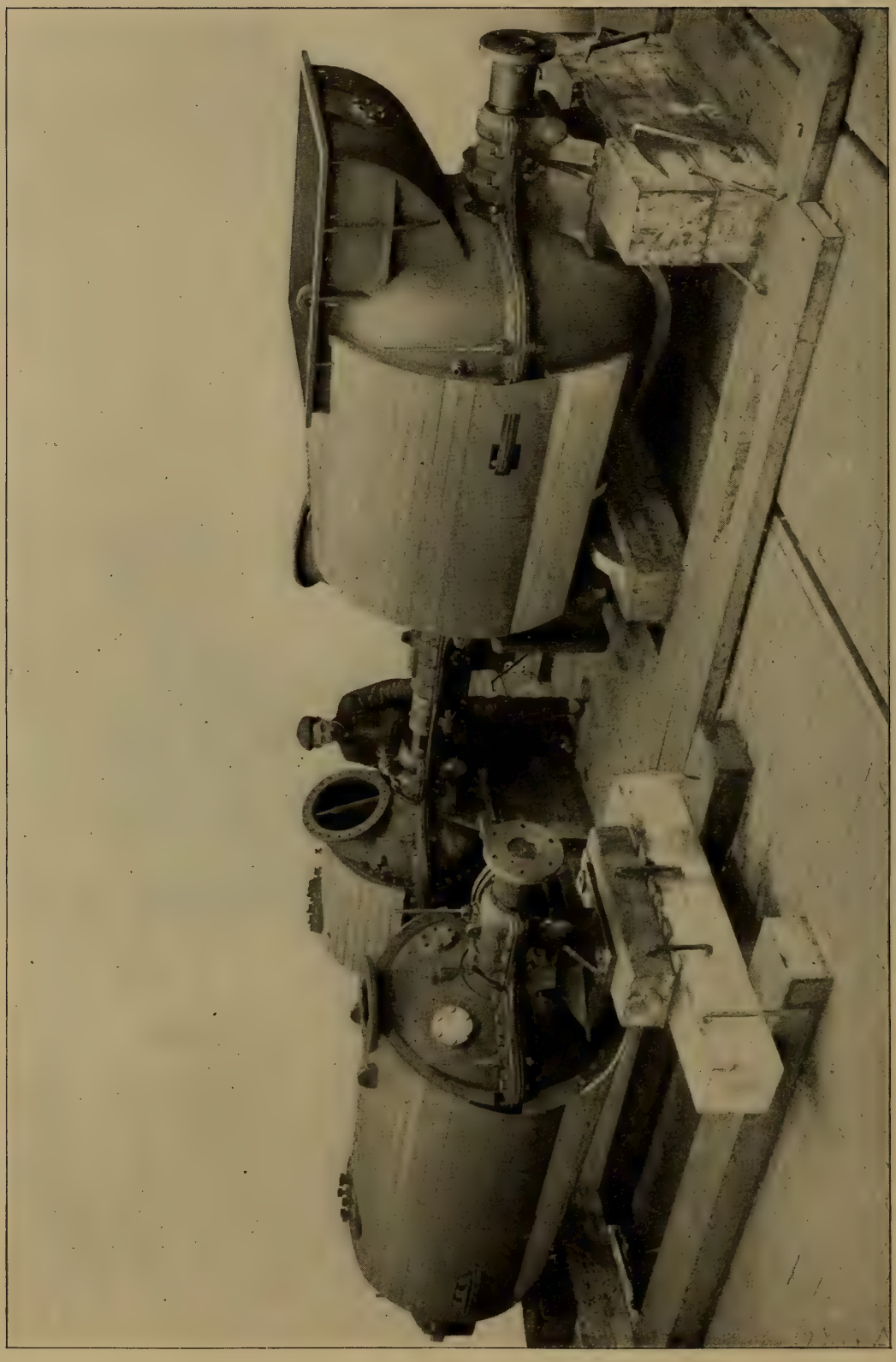
The earliest torpedo-boats were simply steam launches carrying a spar torpedo, and their machinery possessed no special features different from those of any other steam launch. The first specially designed torpedo-boat was the *Lightning*, built in 1877 by Messrs. Thornycroft & Co. for the British Government, and giving a speed of 18½ knots. She was very soon followed by similar boats built by Thornycroft, Yarrow, Schichau, and Normand, who have remained the leaders and specialists in the work of torpedo-boat construction.

The engines of these early vessels were of the compound type, built of the

THE SECOND DESTROYER, "HORNET," OF THE BRITISH NAVY. BUILT BY MESSRS. YARROW & CO., LTD., 1894. THE FIRST ONE TO HAVE WATER-TUBE BOILERS. MAXIMUM SPEED, 27.6 KNOTS

machinery of which the value would be from five to ten times that of the entire torpedo boat. For example, forced draught was a regular practice with torpedo-boats before it was even attempted on any of the larger vessels in recent times. This mention of recent times is necessary, from the fact that forced draught, as is well known, was used on Hudson River steamers, in the United States, in the early part of the last century. In the same way water-tube boilers were used on an extensive scale in torpedo-boats some time before it was considered safe to use them, even experimentally, in large vessels.

lightest possible scantling, and with rotational speeds which were then considered phenomenal. Great care was taken with the details of the design to secure the benefit of the very best material, and wrought iron began very largely to supersede cast iron for everything except cylinders and valve chests. This was before the days of steel castings, which at a later period filled an important place. The boiler was invariably of the locomotive type; that is to say, in general features it resembled very closely the locomotive boilers used on railways. Different designers introduced special features of detail to meet



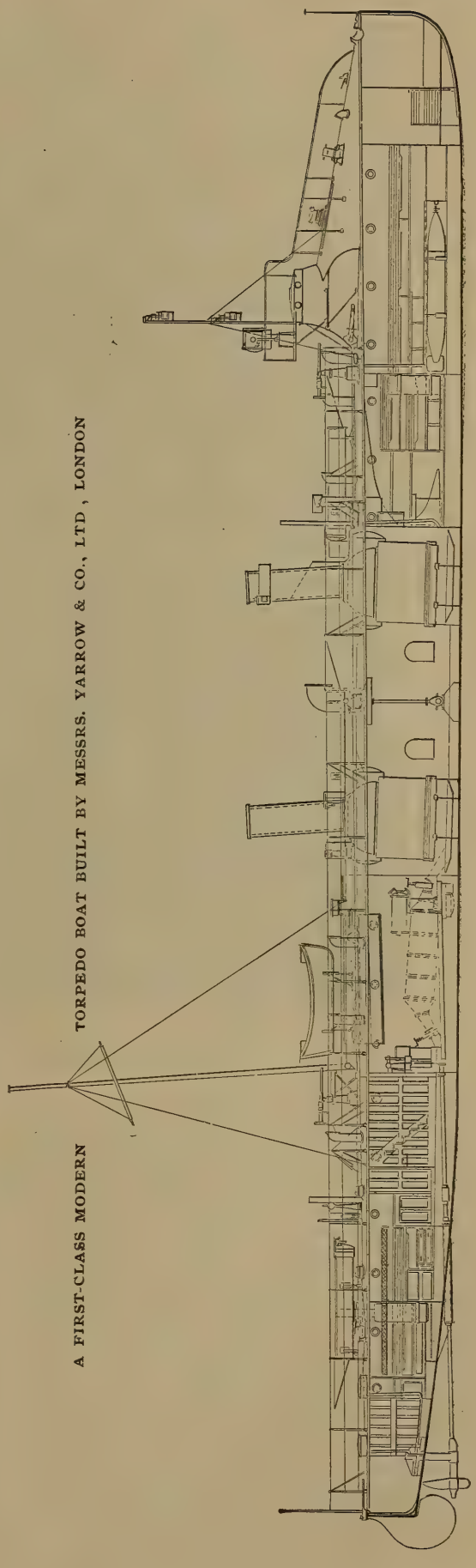
A SET OF PARSONS TURBINES, PORT SIDE, OF THE DESTROYER "VIPER."

defects as they arose; but, speaking generally, the boilers used by different makers were very much alike, and the locomotive boiler remained the only one possible until the advent of the water-tube type.

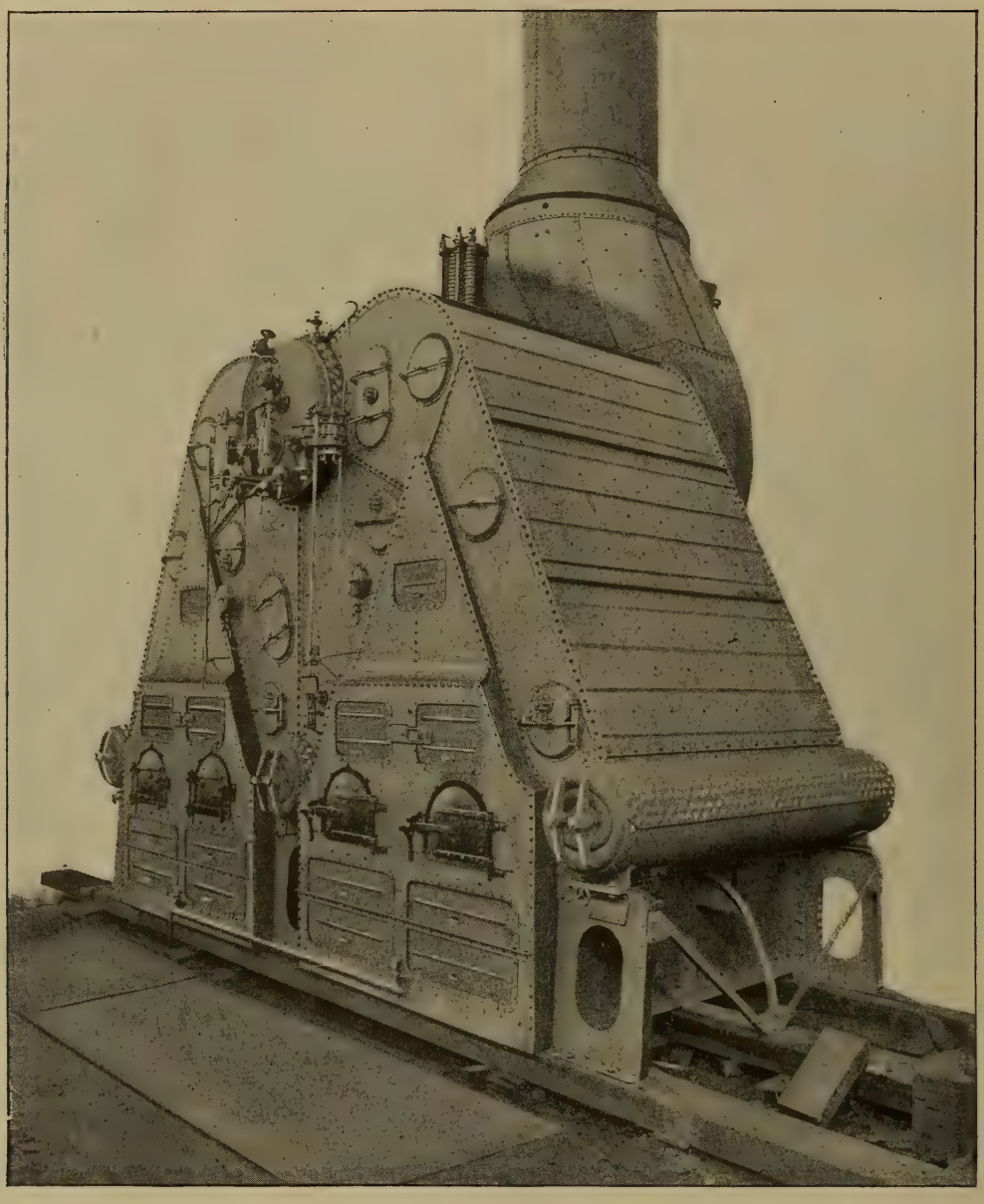
As already stated, forced draught was used from the very beginning in torpedo vessels, and the only limit to the air pressure employed was what the boiler could stand. There are records of pressures having been used as high as 4 inches of water and coal consumption up to nearly 100 pounds per square foot of grate. As the building of torpedo-boats was in the hands of specialists, all of whom were extremely progressive and courageous men, each new class of vessels usually represented the raising of the limit slightly in every respect. As all governments desired to get the very fastest boats possible, there was every incentive to the builders to make each boat an advance over previous ones, as this usually meant large additional orders.

A detail in connection with the boilers may be mentioned here. It consisted of a safety screen over the boiler front. The fire-rooms of these boats were so small and the pressure carried was so high that without this screen, if a tube burst or there was a serious leak, it was almost sure to scald fatally all the firemen. To obviate this the whole front of the boiler was enclosed in a light casing in which there were light, hinged, non-return doors through which the whole of the air had to pass before it reached the furnace. When working, the pressure of air in the fire-room would force these doors open, thence passing down into the ash pit and through the fire-bars. In the case of a burst tube or a serious leak, the steam pressure would at once close the door in the screen and the steam would find its way up the chimney. Several accidents occurred where these screens were fitted, and the men in the fire-room did not know that they had happened until told of it by those who were on deck.

The earliest torpedo-boats were not large enough to keep the sea for long



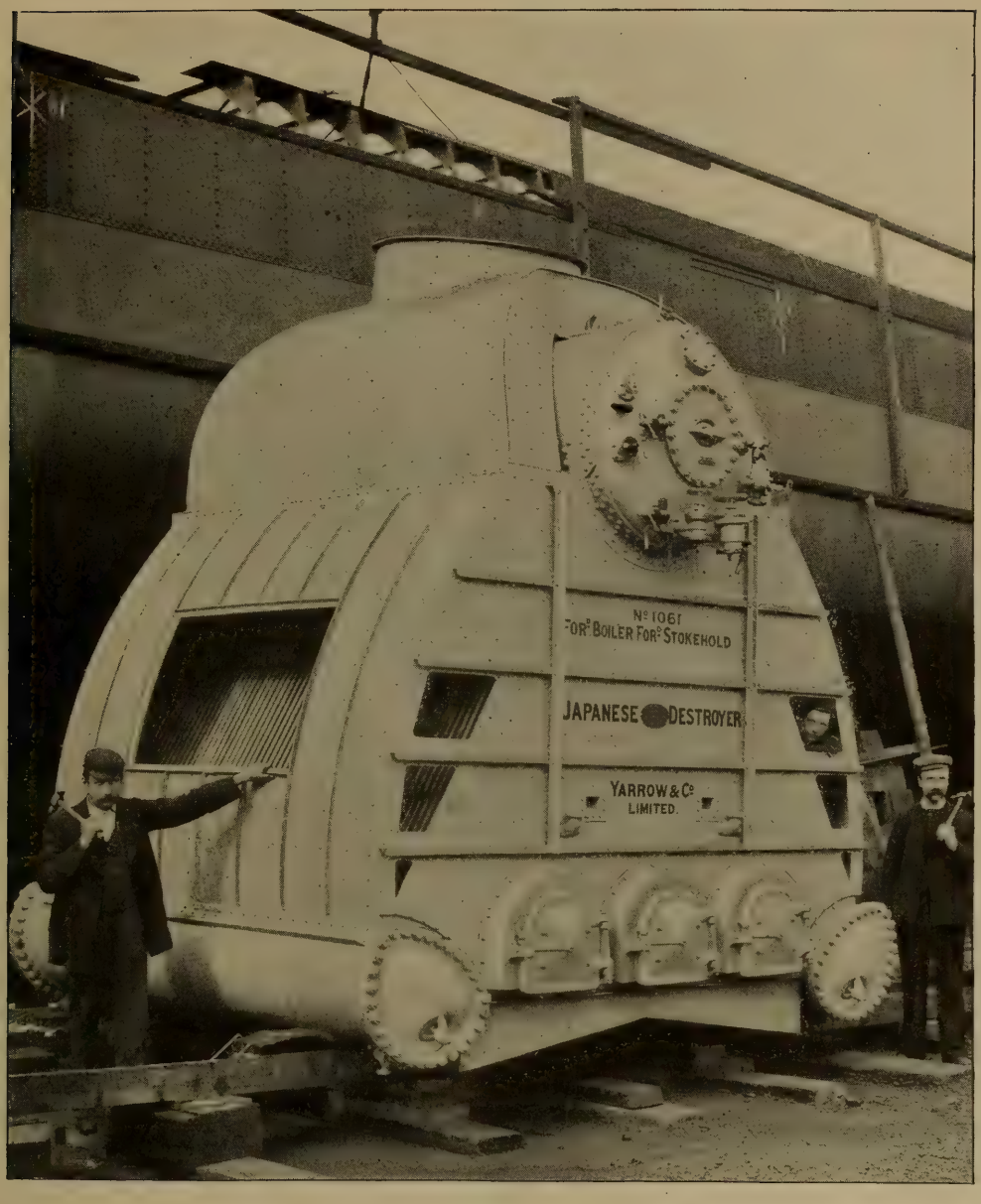
A FIRST-CLASS MODERN TORPEDO BOAT BUILT BY MESSRS. YARROW & CO., LTD., LONDON



WATER-TUBE BOILER BUILT BY MESSRS. JOHN I. THORNYCROFT & CO., LONDON

periods, but about 1880 a larger type of vessel was constructed, known as sea-going torpedo-boats. Since that time nearly all the vessels constructed have been built to keep the sea, although they can never be comfortable vessels in rough weather, owing to their small size. With the growth in size the speed of the vessels increased, and likewise the power of the machinery, until about 1885 the power became too great for a single screw and twin screws were used. Up to this time the engine commonly employed had been the three-cylinder compound, but the efficiency of the triple-expansion engine having been shown in large vessels, it became the type for torpedo vessels also.

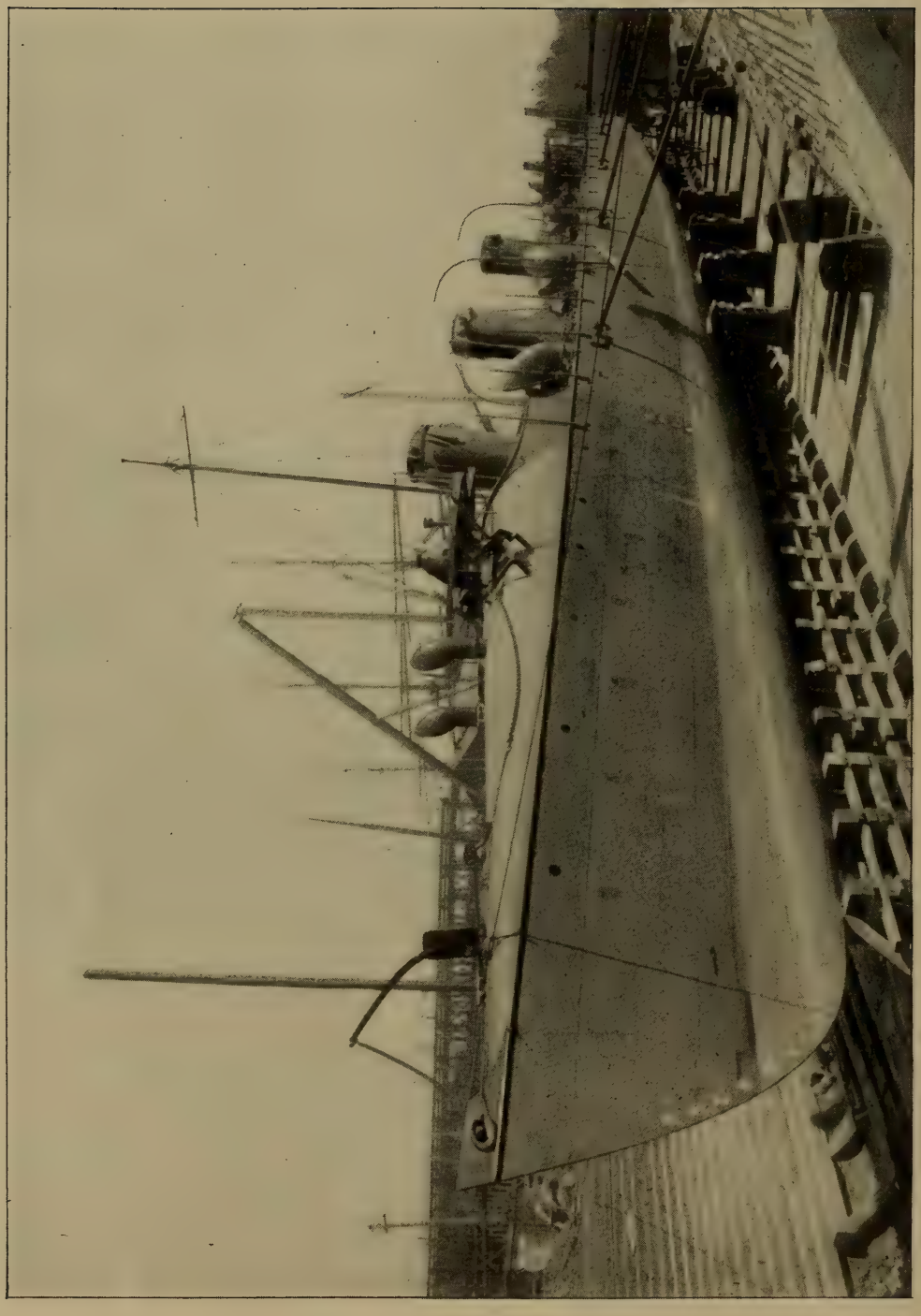
It was on the high-speed torpedo craft that a phenomenon was first noticed, which later appeared also in large high-speed vessels, namely, a serious vibration of the hull. Owing to the very light scantlings of the torpedo vessels and their great relative length, this vibration, when first noticed, was attributed to the action of the propellers; but as speeds increased it was soon found that this could not be the explanation, for the reason that at certain engine speeds there was an entire absence of vibration, while both above and below these speeds



WATER-TUBE BOILER BUILT BY MESSRS. YARROW & CO., LTD., LONDON

the vibration would be excessive. As the phenomenon was investigated it was finally determined that it was in reality an instance of a familiar occurrence, and that the vibration was due to the revolutions of the engine synchronising with a multiple or sub-multiple of the natural period of vibration of the hull. In large vessels at a somewhat later period a partial cure for the difficulty was to change the pitch of the propellers, but as the vibration occurred at a series of speeds in the torpedo vessels, this was not an adequate solution.

Mr. Yarrow, who is justly regarded as one of the most progressive engineers and ablest experimenters in connection with marine work, set out, in characteristic fashion, to determine the cause of the trouble. He first demonstrated that the propellers had little or no effect in causing the vibration by running the engines at the synchronising speeds both with and without the propellers. It was found that with the propellers removed from the shafts, the vibration was practically identical with what it had been with them in place. He then analysed the conditions and finally removed the difficulty by using what he called "bob weights," which were merely weights arranged to run in verti-



THE U. S. TORPEDO BOAT "STRINGHAM" IN THE DRY DOCK AT THE YARD OF THE HARLAN & HOLLINGSWORTH CO., WILMINGTON, DELAWARE

cal slides and driven by small cranks or eccentrics at the ends of the engine. The requisite angular position of these cranks and the amount of the weights could be determined mathematically.

It is to be remembered that all this time the engines which had been giving the trouble were three-cylinder engines of either the compound or the triple-expansion type. While Mr. Yarrow had been conducting his experiments, Herr Otto Schlick, of Germany, had also been studying the problem, and he arrived at an admirable solution, which, from one point of view, is identical with that of Mr. Yarrow, but has the advantage that it employs no relatively useless weights, as in the case of "bob weights." He was probably helped to his solution by the fact that the growth in the size of triple-expansion engines had made the low-pressure cylinder of such large relative diameter that it was desirable, for constructive reasons, to divide the low-pressure stage of the expansion between two cylinders. Herr Schlick's solution, therefore, is the arrangement of the four cylinders so that their distances apart, the weights of the reciprocating parts, and the crank angles will, in effect, accomplish the same result as Mr. Yarrow's three cylinders and the bob weights. It may be said, in passing, that this system gives an almost complete freedom from vibration at all speeds, and it is now adopted not only for torpedo vessels, but for all high-speed engines both in the navy and merchant marine, it being known as the Yarrow-Schlick-Tweedy system.

With the increased powers demanded for high speeds in the larger boats, there had, of necessity, been an increase in the number of the boilers, and as higher pressures and harder driving were demanded, the locomotive boiler was found to be inadequate. Thornycroft was the first to bring out a thoroughly satisfactory water-tube boiler for this work, and the type of boiler was named after the first vessel in which it was employed, the *Speedy*. This type of boiler has been widely used, not only in Thornycroft's own boats, but in those of a great many other makers, and in the earliest American torpedo-boats. It has always given great satisfaction, and when fed with clean water, kept free from dirt and grease, and given a fair amount of attention, it has proved eminently satisfactory. The objection has been raised to it by some that the tubes are not straight; but, as the writer stated some years ago in the pages of

H. M. TORPEDO BOAT "FAME," BUILT BY MESSRS. JOHN I. THORNYCROFT & CO. LONDON

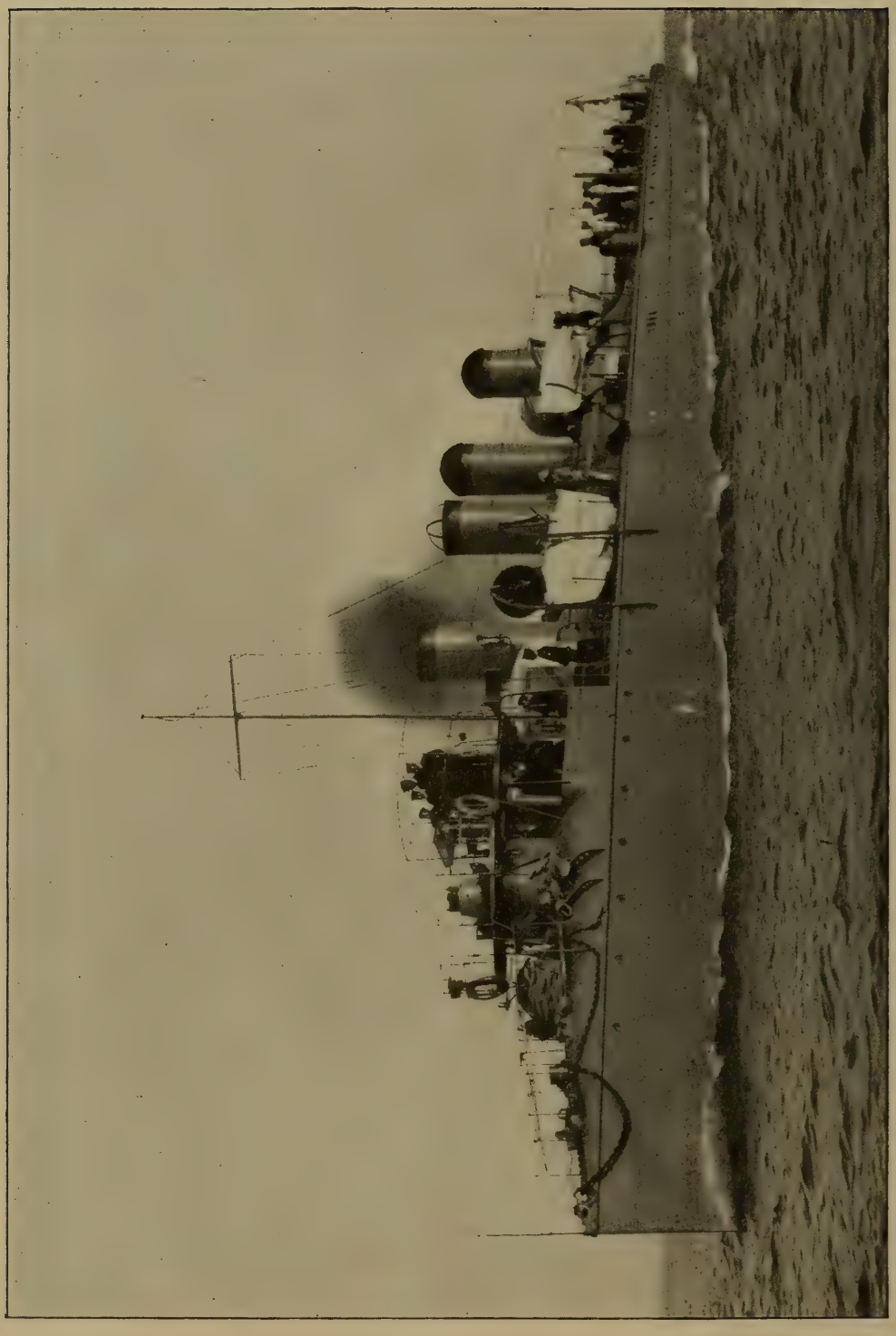
THE JAPANESE TORPEDO-BOAT DESTROYER "USUGUMO." BUILT BY MESSRS. JOHN I. THORNYCROFT & CO., LONDON

this magazine, he does not personally consider this a serious defect, for the reason that the curved tubes can, without great difficulty, be kept clean on the interior surfaces; and there is so great a ratio of heating to grate surface that defective tubes can be plugged for a long time without materially reducing the economy of evaporation, thus meeting the objection of difficulty in replacing a defective tube. The curvature of the tubes enables certain very decided advantages to be obtained in the baffling of the gases on their way to the chimney, and the writer believes this to be of very decided moment. The *Speedy* type of boiler is not so economical of space as might be desired, and this led Thornycroft to bring out what was known as the *Daring* type, which has secured economy in space occupied.

Normand about the same time brought out a boiler resembling in many features the Thornycroft, particularly in baffling the gases on their way to the chimney, although the course of the gases is different. His boiler also uses what are called "wholly submerged tubes," while the *Speedy* type of boilers has the tubes delivering above the water level. Yarrow, with his accustomed skill, has brought out a highly efficient boiler which has the great advantage, to many engineers, of having straight tubes. With these it was impossible to get the same baffling effect as in the boilers of Thornycroft and Normand, so he ingeniously arranged to use the outer rows as feed-water heaters, thus reducing the stack temperatures to moderate limits. An almost endless number of water-tube boilers has been brought out resembling more or less those already mentioned, some of them by engineers in the United States, including the Mosher, the Ward, the Cowles, the Towne, the Herreshoff, and others. It should be stated that all of these boilers for torpedo-boats are of what is known as the "small-tube type," that is to say, the tubes are never more than an inch and a half in diameter. With this small diameter they are, of course, correspondingly thin, so that it is possible to obtain an enormous amount of heating surface for a relatively small weight. For example, the boiler of the U. S. torpedo-boat *Cushing*, which is of the *Speedy* type, weighs, empty, nine tons, and including water, eleven tons. With an air pressure of 4 inches of water, and burning sixty-six pounds of coal per hour per square foot of grate, this boiler developed a horse-power of 912, giving 82.95 I. H. P. per ton of boiler and water. The British boat *Desperate*, a Thornycroft boat of 1896, obtained a horse-power of 87.2 per ton of boiler and water.

While discussing this question of water-tube boilers in torpedo-boats, it may be mentioned that besides the advantage they possess in a very important reduction of weight, they also have the great advantage that they will stand almost any amount of forcing without injury. Mr. C. D. Mosher stated before the Engineering Congress in Chicago in 1893 that he had once tested one of his boilers with an air pressure of 12 inches of water without any serious results, the boiler showing no fatigue and every joint remaining absolutely tight

Like all other boilers, however, it is necessary that they should have an adequate supply of water, and a sad accident, resulting in the death of six men a few years ago, showed the importance of this fact As all the men were killed who could have had any actual knowledge of conditions before the accident, the cause had to be inferred from the condition of the boiler. In this particular case twenty-five or thirty tubes pulled out of the steam drum, and inspection gave every evidence of overheating. From the location of the boiler and the change in trim under high speed, known as "squatting," it was believed that the men had not been careful to carry the water high enough to keep these tube ends properly covered with water, and that, although they would have been so covered with the vessel at normal trim, when she "squatted" under full speed the ends of these tubes had only steam on one side and the full temperature of the furnace on the other, with the result that the tube plate was overheated and the tubes pulled out.



ONE OF SIX 31-KNOT TORPEDO-BOAT DESTROYERS BUILT BY MESSRS. YARROW & CO., LTD., LONDON, FOR THE JAPANESE GOVERNMENT. THIS REPRESENTS MESSRS. YARROW'S LATEST TYPE

Of course, all the steam from the boiler was poured into the closed boiler compartment and killed all the men who were there. It may not be amiss to remark that the boiler itself was not seriously injured, and when the damaged tubes were replaced the trial which the boat was undergoing was carried through successfully. In contrast with this, it may be noted that about three or four years previously a locomotive boiler exploded, owing to low water, which caused the copper fire-box to collapse. Not only was every man in and near the fire-room killed, but the boiler was completely wrecked and the deck above it torn up.

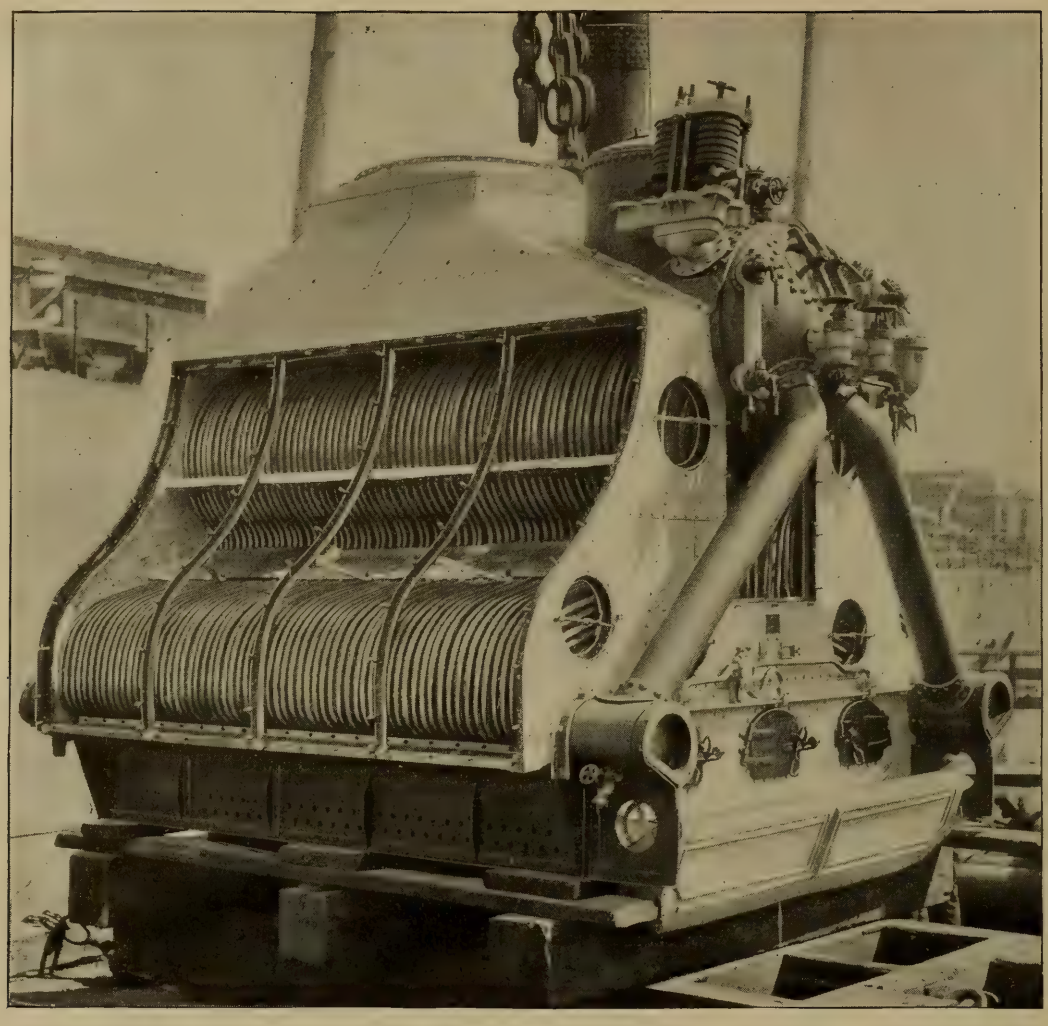
Mention should be made in any history of torpedo-boats of the work done by the Herreshoffs, in America. Although the actual number of naval torpedo-boats built by them has not been large, they did a great deal of splendid pioneer work in fast steam yachts and launches, and they were among the first to build very light high-speed machinery and to use water-tube boilers. The *Cushing*, the first United States naval torpedo-boat of modern type, was built by them, and proved very successful.

As has already been mentioned, even large torpedo-boats are anything but comfortable at sea, and about 1893 naval authorities felt that if the full benefit of this class of vessels was to be obtained they must be made enough larger to enable them to keep the sea in all weathers without rendering their crews unfit for duty. This brought about the construction of the class of vessels known as the "torpedo-boat destroyer," or, as it is usually abbreviated, simply "destroyer" As far as the machinery is concerned, this made no difference, except an increase in size. The latest destroyers for the United States Navy have machinery of 8000 horse-power in a hull displacing about 400 tons. These vessels are rather larger than the destroyers of other navies, and a few knots speed were sacrificed for the sake of getting vessels large enough to be really self-supporting.

It would seem obvious that where weight is so precious as in a torpedo vessel, economy would play a secondary part, and such is indeed the case. In fact, at full power most of the torpedo vessels have a coal expenditure of about two and a half pounds per I. H. P. even with triple-expansion engines and over 200 pounds steam pressure. A part of this reduced economy is due to the reduced economy of evaporation. For example, a series of progressive trials of the *Cushing's* boiler showed that while there was an evaporation (from and at 212° Fahr.) per pound of coal of 9.7 pounds of water with half an inch air pressure, the evaporation was only 6.5 pounds with 4 inches air pressure. There is also a reduced economy of the engines, which, as can be readily imagined, are not, as a rule, jacketed, and can have few appliances specially designed for economy.

While this is the general rule, attention must be called to the difference in this respect of some of the machinery built by Normand, in France, who has taken unusual precautions to get great steam economy in the engines, thereby reducing the amount of boiler power required, and, as he claims, with a material saving of weight on the whole. He has discussed this matter with reference to one of his most famous boats, —the *Forban*,—and estimates that the greater economy in the engines actually enabled him to save one boiler.

As was mentioned earlier in this article, every care is taken in torpedo-boat machinery to get the very highest grade of material and to adopt such a design as will, of itself, reduce weights to a minimum. For example, all shafting is made hollow, although the external diameters are such that for larger vessels they would be made solid. The new United States destroyers have crankshafts with an external diameter of 8½ inches, pierced with an axial hole 4¾ inches in diameter. The thrust, line, and propeller shafts are 7⅞ inches in diameter, with 4¾-inch axial holes. The crankshafts are made in two sections, each of which is a complete forging. It can readily be understood that these finished forgings bring a very high



A REED WATER-TUBE BOILER AS FITTED TO TORPEDO BOAT DESTROYERS BY PALMER'S SHIPBUILDING AND IRON COMPANY, LTD., JARROW-ON-TYNE, ENGLAND

price, and it has been stated that they cost the builders in the neighbourhood of $1.50 per pound finished and ready to put in the bearings. The piston rods, although only of 4¼ inches outside diameter, have axial holes 2¾ inches in diameter through them. The connecting-rods are 3⅞ inches in diameter at the small end and 4⅝ inches at the large end, but they also are hollow, with an internal diameter of 2¼ inches.

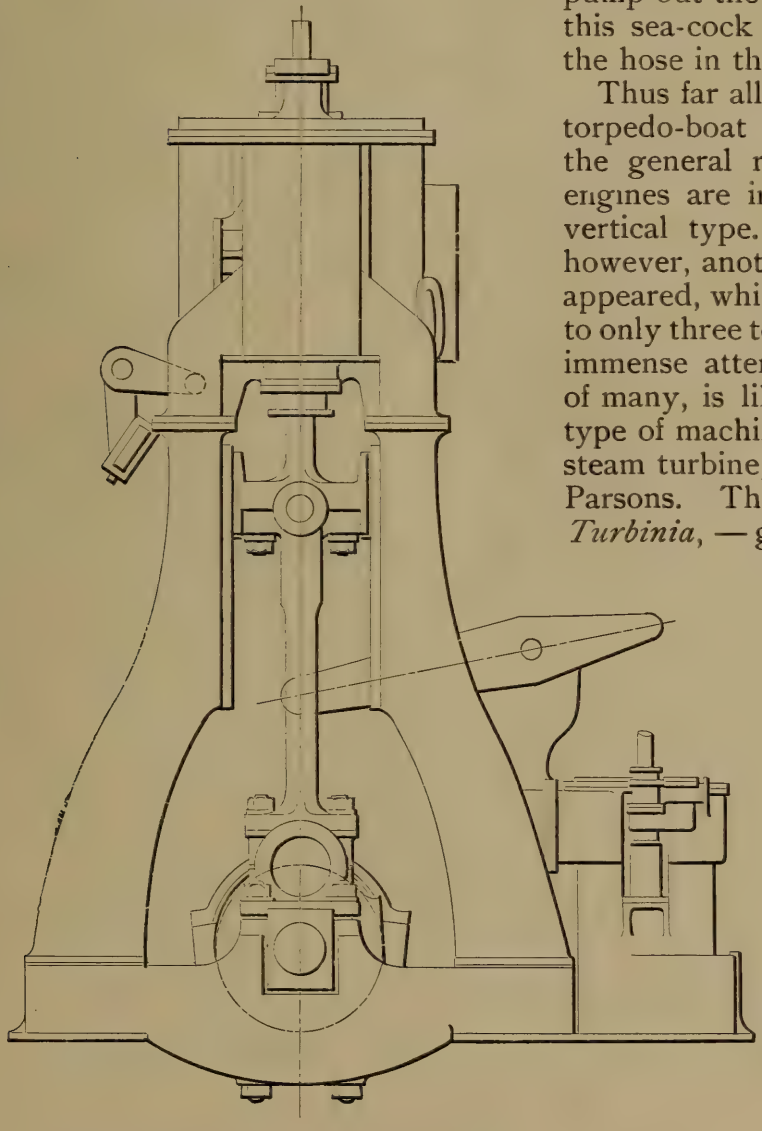
As showing further the efforts made to save weight, it may be stated that the piston valves, instead of having packing rings, as is customary with those for large engines, are made with plain ends. They are turned and polished with emery to fit their linings accurately. The linings themselves are also polished with emery after boring.

The steam pressure in these boats is 250 pounds at the engines and 300 pounds at the boilers. As is now well known, copper pipes, other than those which are seamless, are not satisfactory for these high pressures, so that in these vessels all steam piping above 2 inches in diameter is of steel. Pipes smaller than 2 inches are of copper. With such high pressures there is also difficulty in securing tight joints when made in the old style with the ordinary flat grooved flanges. In these vessels, for all pipes carrying more than 200 pounds pressure, the flanges are made male and female, and special packing material is employed.

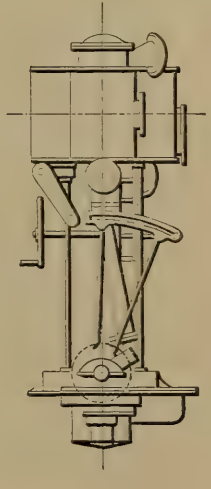
A feature in connection with torpedo-boat machinery, interesting to those who are not familiar with it, is the way in which the circulating water is sent

through the condenser. The speed of the vessel is so high that for anything approaching full speed the vessel is, so to speak, made its own circulating pump; in other words, scoops are fitted upon the bottom of the ship so that the motion of the vessel causes the water to flow through the condenser tubes without using any circulating pump. The result is highly efficient, and the amount of cooling surface per horse-power in torpedo-boat machinery is very low. A small circulating pump of the centrifugal type is fitted for giving an adequate circulation when the vessel is moving slowly. A rather interesting point in connection with this is the fact that at high speeds, without the scoops, not only would the water not run into the boat, but it would actually be pumped out. In some of the early boats, although scoops were fitted for the main injection openings, it had not been thought necessary to provide them for the small openings for admitting water to the ash hose. It was found at full speed that no water would come in through the hose, and the reason was not at first apparent; then it became necessary to slow down enough to let the water run in. When running at full speed it was actually possible to pump out the bilge by simply opening this sea-cock and dipping the end of the hose in the bilge.

Thus far all that has been said about torpedo-boat machinery has been for the general run of vessels where the engines are invariably of the inverted vertical type. In the last few years, however, another type of machinery has appeared, which, although thus far fitted to only three torpedo-boats, has aroused immense attention, and, in the opinion of many, is likely to displace the older type of machinery. This engine is the steam turbine, invented by Hon. C. A. Parsons. The first of his vessels,—the *Turbinia*,—gave wonderful results.

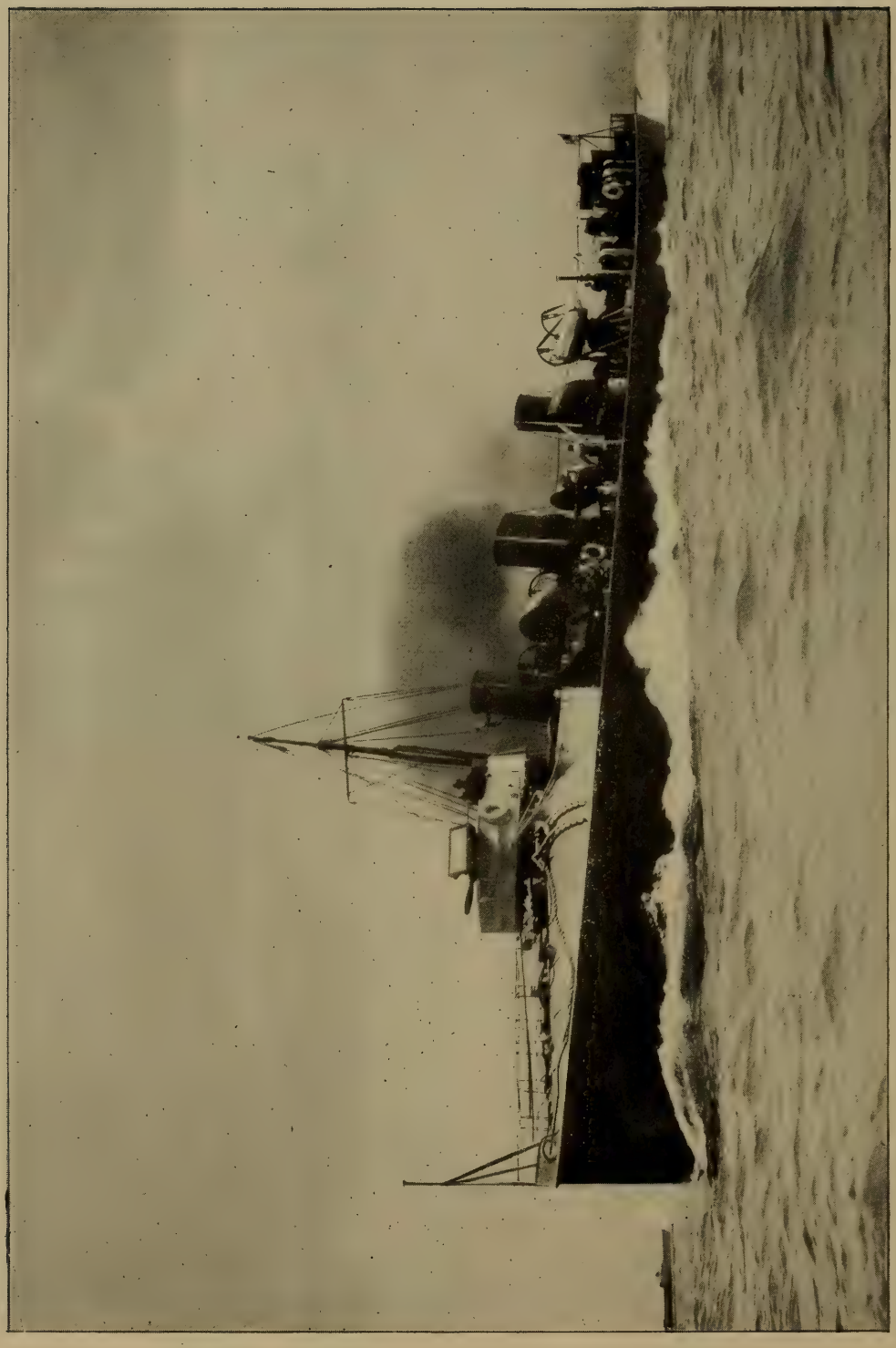


ENGINES OF 1,000 H. P. AS CONSTRUCTED IN 1872



ENGINES OF 1,000 H. P. AS CONSTRUCTED TO DAY

THESE DIAGRAMS, SHOWING ENGINES OF EQUAL POWER, ARE DRAWN TO THE SAME SCALE AND ARE INTERESTING ILLUSTRATIONS OF THE PROGRESS MADE IN TORPEDO-BOAT MACHINERY



A DESTROYER BUILT BY PALMER'S SHIPBUILDING AND IRON COMPANY, LTD., JARROW-ON-TYNE

She is a little vessel of only 44.5 tons displacement, yet her machinery developed 1576 horse-power. There were three turbines driving three shafts, each of which had three propellers in tandem, thus making nine propellers in all. This unusual number of propellers was rendered necessary by the very high speed of the turbines,—2100 revolutions per minute. Indeed, the design of the propellers was one of the most difficult features in this boat, for the high speed introduced problems which had never before come up The speed was far higher than had ever been obtained in a boat of her size, being 31 knots. The special advantages of the turbine are the complete absence of vibration, the great simplicity of the motive machinery, and the entire absence of danger due to priming in the boilers. Wet steam reduces the economy with which the turbine works, and also the rotational speed, but actual experience has shown that there was no harm whatever done, even by excessive priming.

The *Turbinia* was tried in 1897. Last year two other turbine-propelled vessels of the destroyer class were built, called the *Viper* and *Cobra*. These vessels are 210 feet long, 21 feet beam, 12 feet 9 inches deep, and have a trial displacement of 370 tons. There are four shafts, each having two propellers, or eight in all. There are two sets of compound steam turbines for driving the vessel ahead, and special, smaller turbines are provided for driving the vessel astern. The best speed obtained by the *Viper* was 37 knots, the mean revolutions being about 1050 per minute, and the mean steam pressure, 165 pounds. There are four Yarrow boilers with a grate surface of 275.75 square feet, and 15,000 square feet of heating surface. The average air pressure was three inches of water. The indicated horse-power was about 11,000.

It may be mentioned here, as comparatively little is as yet known about the performance of steam turbines, that their economy at full power, and for a considerable range, is excellent. While the writer has found no records of the steam per horse-power of these torpedo-boats, experiments made with steam turbines built by the Westinghouse Machine Company, of Pittsburgh, Pa., showed a steam consumption equivalent to 14 pounds per indicated horse-power-hour in an ordinary engine. At half power the consumption had increased to only 15.4 pounds per indicated horse-power-hour.

A question which is always of interest in connection with all marine machinery, and particularly with torpedo-boats, is the use of liquid fuel Its obvious advantages in the way of convenience of storage and rapidity of receipt are in its favour, while the much higher calorific value than that of coal and the close fire regulation possible, as well as the immediate effect of its combustion, would all commend it very highly. Experiments have been made in many countries to determine its adaptability, and some very interesting experiments made in Italy about 1892 showed that a common opinion is erroneous, namely, that the use of steam for spraying the oil would be inadmissible on account of the large amount required. The Italian experiments showed that a high efficiency in the use of oil could be obtained with an expenditure of less than 2 per cent. of the amount of water vapourised. This would be the simplest way to secure the spraying of the oil, as it would do away with the somewhat complicated machinery needed for compressing air if that were used.

There are two very serious objections, however, to the use of oil. One is that there are relatively few places where fuel oil could at present be obtained, along with the fact that any extensive demand would probably raise the price so as to make it more expensive than coal. The second objection, however, is the more serious one, namely, that thus far it has been found impossible with liquid fuel to obtain as great an amount of power from a given boiler as when good coal is used. In 1897 and 1898 some experiments with oil fuel were made under the direction of Admiral Melville, U. S. N., on the little torpedo-boat *Stilletto*, and in many respects they appeared very promising.

WEIGHTS OF MACHINERY OF TORPEDO VESSELS

Name	Date	Weights in Tons				I. H. P. per Ton of			Remarks
		All Machinery and Water	Main and Auxiliary Engines Only	Boilers and Water	Water in Boilers	All Machinery	Engines Only	Boilers and Water	Water in Boilers	
U. S. S. Cushing	1889	54.5	24.5	30.0	3.5	32.29	71.82	58.67	502.9	Thornycroft boilers, Speedy type, 250 lbs. pressure.
H. M. S. Ferret	1894	123.6	59.4	64.1	11.5	36.30	75.20	69.70	389.7	Normand boilers, 175 lbs. pressure.
H. M. S. Janus	1895	120.0	49.0	70.7	7.95	31.58	77.30	53.60	477.0	Reed boilers, 210 lbs. pressure.
H. M. S. Desperate	1896	127.95	61.5	66.46	7.75	45.30	94.30	87.20	747.0	Thornycroft boilers, Daring type, 215 lbs. pressure.
H. M. S. Quail	1897	144.3	68.6	75.7	11.25	41.97	88.40	80.10	539.0	Normand boiler, 220 lbs. pressure.
U. S. S. Foote	1897	50.82	24.5	26.32	4.0	47.22	97.96	91.19	600.0	Mosher boilers, 240 lbs. pressure.
U. S. S. Farragut	1898	120.0	56.8	63.2	10.5	46.67	98.58	88.58	533.4	Thornycroft boilers, Daring type, 250 lbs pressure.
U. S. Destroyers	1898	189.1	89.8	99.3	15.9	42.30	89.08	80.56	503.1	Water tube boilers, 300 lbs. pressure.
U. S. Torpedo Boats	1898	79.75	35.5	43.75	6.6	37.62	84.5	68.58	454.5	Water tube boilers, 300 lbs. pressure.
LARGER NAVAL VESSELS										
U. S. S. San Francisco	1888	914.0	433.0	481.0	125.5	10.63	22.44	20.20	77.43	Shell boilers, 135 lbs. pressure.
U. S. S. Oregon	1892	1068.4	436.4	632.0	143.2	10.38	25.46	17.58	77.58	Shell boilers, 160 lbs. pressure.
H. M. S. Diadem	1898	1436.7	688.3	748.4	39.0	12.01	25.08	23.07	442.6	Belleville boilers 300 lbs. pressure.
H. M. S. Cressy	1898	1800.0	858.0	942.0	49.3	11.67	24.47	22.29	425.9	Belleville boilers, 300 lbs. pressure.

During 1900 these experiments were repeated on a larger scale on the torpedo-boat *Talbot*, but the results have thus far proved disappointing, and the apparatus for burning oil fuel has been removed for the present. In his annual report for 1900, Admiral Melville says:—

"The best type of jet or spray burner yet used on the *Talbot* has failed to secure power for a sustained speed of more than three-fourths the full trial speed of the boat, even for half an hour, while the smoke feature is equally as evident as with soft coal, except at a speed as low as 10 knots. It may be added that the burners used for experiment were selected as the best in the market, and as having given best results in extended use on shore."

The table on this page gives some data taken from an article by Admiral Melville and already published in this magazine, showing the weights and some other particulars of the machinery of some recent torpedo vessels, and in order that an idea may be obtained of the enormously increased power from a given weight, there are also appended a few figures for similar details of large vessels. From these it will be seen that even where the large vessels are equipped with water-tube boilers, the torpedo vessels get nearly four times the power out of a given weight.

Torpedo-boat machinery has been developed to a very high degree. The men who have made a specialty of this class of work rank not only as the leaders in this particular line, but among marine engineers generally. As has been noted, in the change from locomotive to water-tube boilers, and in the method of preventing vibration, they have met and solved the difficulties as they arose. The difficulties attending higher powers are met, to a certain extent, by the steam turbine. This, however, has thus far involved the use of a larger number of shafts and propellers than the ordinary type of machinery, and has the objection of requiring additional turbines for backing.

Just what the next step in progress will be is not at present perfectly clear.

The wonderful results obtained from the turbine-propelled boats would seem to indicate these as the means of the next most important development. In any case, we can rest assured that the talented men who have brought torpedo-boat machinery to its present high state of efficiency will not be daunted by any obstacles which may confront them, but will repeat their triumphs of the past and go on to still greater ones in the future.

MACHINE MOULDING

By Joseph Horner

MACHINE moulding has developed more rapidly in America than in Great Britain. The explanation for this is specialisation,—the same cause which has contributed more than any other to the development of automatic machinery. The moulding machine is not new, either, for it was used forty years ago in England. It has long been employed in British railway shops for making chairs and brake blocks; in the agricultural works, in the foundries of the cotton machinists, in a few brass foundries, and by the makers of iron cocks and valves. But a single firm in America will now use as many machines as would be found in an entire district of large area in Great Britain. And of the many moulding machines made in large numbers in the States, comparatively few have yet got into British works.

To understand the economies of machine moulding it is desirable to state concisely the ordinary methods of hand work. In one system a pattern is bedded down into the sand which forms the foundry floor, and is covered by a top box, or cope, which, being rammed over the upper face of the pattern, forms the impression of that portion. This is suitable only for certain classes of work, into the reasons for which it is not necessary to enter. In the other method, which is that adapted for by far the largest majority of work, the pattern is bedded in a temporary mould, the only purpose of which is to provide a suitable face on which to commence the actual moulding. That is, the position of the pattern has to be adjusted relatively to the joint of the box, and the sand joint made by the hands or the trowel, exactly where the joint of the actual mould has to come. Then the work of moulding begins on this joint face, and over that portion of the pattern which is exposed, and after this is done the temporary work is knocked out, and the section of the moulding box which was utilised for it is then laid upon the part mould just completed and rammed properly. There is, therefore, always a full box of sand thrown away, and the task of making a joint face by hand is involved. This joint face in certain classes of work is of irregular outline, and occupies a large amount of time, but it has to be made for every mould.

Now the first advantage of machine moulding is that the time required for making the temporary mould and its oint face is saved. And, in addition, the labour is saved of cutting the ingates, through which the metal has to enter the mould. These have to be cut in every mould by hand and trowel, while in machine work the patterns of these also are put on the pattern plates.

Again, after the mould is rammed, the rapping and the withdrawal of the pattern by hand are a source of frequent trouble, since the sand becomes fractured by reason of the unsteadiness of the workman's hands and of the difficulty of controlling the withdrawal in a plane perfectly normal to the face of the mould. This in itself is one of the most serious causes of want of uniformity in the dimensions and shapes of castings moulded from the same pattern. Yet this is under perfect control in a machine, and affords one of the clearest advantages of machine moulding, not only with regard to the act of withdrawal, but also in lessening the amount of rapping necessary for loosening the pattern, which is a fruitful cause of differences in dimensions of castings.

A half-way device which saves waste of time involved in bedding in the pattern in a temporary mould and making the joint faces is plate-moulding. Another is the odd-side moulding of the brass founders. In the first, the pattern is put permanently on a plate, the faces of which provide the necessary joint faces, and to which the ingate patterns also are generally attached. In the second, the patterns are bedded loosely in a dummy mould of hard rammed sand, or plaster, or other composition, which also forms the joint face. These are merely extensions of the common device of employing joint boards, or bottom boards. But though the plates and the odd sides are a great advance on the usual methods, they lack the important provision for the mechanical withdrawal of the pattern. This the moulding machine provides.

In moulding by machine, impressions may be taken directly from divided patterns, parts of which are placed on both sides of one plate, or by portions of patterns on one side only of separate plates. With regard to the first method various practices are followed in making and mounting the patterns. Those of wood are used to a considerable extent in foundries where machine moulding is done. Where the patterns are of large dimensions, or when but a limited number of castings is required, wood is more economical and nearly or quite as suitable as metal. Such patterns are often screwed to metal plates, though sometimes to plates of wood.

With regard to patterns of metal, these also are generally screwed to plates of metal. Frequently, too, they are cast in one with their plates, a practice to which there are objections in some cases, because it affords less chance for cleaning up the patterns and plates than when they are made separately. In high-class work it is better, as a rule, to prepare the patterns separately and attach them to plates, planed, or milled, or ground truly, using sheet-steel, or iron, or castings for the latter. The ingates also are generally made as separate pieces, and attached. To ensure the matching of the edges of castings moulded from plates in which pattern parts are put on both sides,—which includes the greater number of moulds made,—dowel holes and screw holes are generally put through both halves of the pattern, and these can be reattached through holes in the plate, drilled directly from one-half the pattern. The top and bottom parts of the mould, then rammed on opposite sides of the plate, are bound to match each other.

To say off-hand that any one moulding machine is the best to use in a shop is not possible, because everything depends on the character of the work done. The moulding machine now forms a large genus, and is becoming as highly differentiated as some classes of machine tools. Hence, there is no machine and no system of machine moulding of which it can be said that it is the best possible under all conditions. The requirements of individual shops must be known before any decision can be come to, either as to the selection of the best machine or the best system which should be adopted. The question is, first, one of dimensions, then of simplicity, or intricacy, of form, then of the number of similar pieces wanted. Again, in some shops little assistance can be derived from moulding machines; in others nearly everything can be done on them.

All kinds of castings are not profitably adapted to machine moulding.

Those of very large dimensions are generally excluded, notwithstanding that the capacities of moulding machines have been greatly increased in recent years. Castings of great depth and intricacy are ill suited to this method. But work having a considerable amount of detail, provided it is shallow, is eminently adapted for the machine. It is not easy to state the case in general terms. But fairly deep work, provided it is plain, is much better lifted by machine than by hand, for reasons previously given. But a machine will lift only vertically, while some patterns have to be drawn out at an angle, or with a special twist; or drawbacks or loose rings of sand will modify matters so much that the machine would rather complicate than simplify moulding. Work with middle parts is not adapted for machine moulding. Cylindrical sections are highly adaptable. The best of all is that which is shallow, and easy to ram and deliver. And the highest economies are obtained by the grouping of numerous small pieces on one plate. It is obvious that for work in which the making, setting, and fixing of cores occupies more time than the actual moulding of the pattern, the economies of machine moulding are not so great as that in which the conditions are reversed.

Though it is true that the more highly specialised the work of a foundry is, the greater are the economies effected by machine moulding, yet too many firms make the mistake of thinking that machines are economical only when a large volume of work has to be done. A few dozens of moulds will often pay for putting the pattern on a machine, for, like turret lathe work, when a firm gets into the system, the time occupied in fixing up a given job tends to diminish.

Since the question is always one of economic means to an ecomonical end, we may briefly consider the leading features only of modern machine moulding. The first question that naturally arises is that of hand *vs.* power ramming. Many years ago, when the advantages of machine moulding were first grasped, attempts were made to save the labour of hand ramming. Scores of patents have been granted for devices by which this was to be avoided. But the difficulty in all has been to ensure equal ramming over areas in which sand is of different depths, and alike against horizontal and nearly vertical faces. Uniform consolidation of the sand is difficult in such cases, and apart from the use of special presses, either rigid or elastic, the contours of which follow approximately the contours of the pattern being rammed, it is impossible to obtain uniform results. Another practical point is that in many moulds it is desirable to ram some parts harder than others, and to give special attention to weak and slender parts by using a different grade of sand, by local moistening with water, or clay water, by the insertion of nails and rods, devices of which a moulder fully understands the necessity, but which are not provided for by machine-ramming. For those classes of work in which these necessities do not exist, and they constitute a large number, machine-ramming fills a useful place.

In some very successful modern types of machines no attempt is made to use power for ramming, the functions of the machine being limited to the advantages derived from plating patterns and gates, and to their withdrawal. It is concluded, therefore, that if the class of work done in any shop is such that no economy can be derived from the application of power to ramming, then it is far better to install hand machines, and save the expense and complication of pipes and power plant.

The difference in the time occupied in hand-ramming or machine-ramming is not always so great as to be an important factor in the calculation of total time saved by machine over hand-moulding. The saving obtained is due in a much greater degree to other advantages. The economy lies in the system itself, which involves putting patterns on plates, on gating, on true vertical lifts, on the training of unskilled men to do work otherwise done by skilled moulders, and to the difference between jobbing and repetitive work. By comparison with these the single

detail of ramming is of little importance. The next question is that of the withdrawal of patterns, and this is nearly as important as that of ramming. It is a clear gain, to the advantage of the work done on a machine, if the uncertain element of rapping, with enlargement of the mould which it produces, be eliminated, and the castings be turned out uniformly to dimensions. But some patterns of considerable depth and little taper refuse to draw without fracture of the sand unless they receive a considerable degree of loosening, or alternatively, unless the sand over them is confined by a stripping plate; and so we find these two devices in use, the vibrator system, and the closely fitting stripping plate through which the pattern is drawn, and regarding the relative values of which opinions differ.

In rapping a pattern by hand, the vibration is chiefly confined to the pattern, and the effect is to widen the boundaries of the sand by which it is enclosed. But in jarring the platen of a machine the vibration is communicated to the sand equally with the pattern, and there is some risk of the sand becoming loosened and breaking down at the time of withdrawal, a tendency which is aggravated when it has been consolidated by power pressure instead of hand ramming judiciously moderated in different parts. For this reason the vibration of the mould is not regarded so favourably as withdrawal through a stripping plate. This is most efficient, for the deepest pattern can be drawn through a plate without fracture of the sand. But the objection to the device is its expense, and the cost must be discounted by the numbers required from a given pattern.

Yet neither is the question of the use of stripping plates of a general character to be settled off-hand for all jobs alike. Mainly, the question is one of shape of the pattern. Anything which is shallow, with tapered or rounded edges, does not need a stripping plate. Neither do semi-circular patterns, even though of considerable depth, provided there are no square shoulders left at the ends. When work of this kind will permit, plenty of taper is put at such ends. Patterns, on the other hand, which are deep and square at the edges cannot be drawn on a machine by rapping alone. Spur-wheels are a case in point. Even though shallow, these must be drawn through plates.

The usual method of fitting stripping plates around patterns is by filing, which, in the case of those having irregular outlines, becomes expensive. In one instance plates are fitted at less cost by casting a zone of Babbitt metal in the plate around the pattern, with the result that it takes the outline of the latter. The iron plate itself is cast roughly with an opening about an eighth of an inch round the pattern. Its upper edge is recessed to a width of half an inch and a depth of 3/8 inch, and is drilled with holes spaced at about 3/4 inch apart, wire nails being driven in with the heads about 3-16 inch below the surface. Both top and bottom faces having been tooled, the plate is laid around the pattern on the machine, asbestos string is placed between the backing of the pattern and the opening cast in the plate, putty is laid round the top of the plate, and Babbitt metal is poured in. After a little trimming of faces and edges the plate is ready for use.

Another matter which has received considerable attention of late years is the question of fixed *vs.* portable machines. The earlier types, and probably the largest number still in use, whether operated by hand or power, are fixed. This, though unavoidable in power machines, is not so in those machines which are hand-operated. It has now become evident that by mounting machines on wheels certain economies may be effected in the saving of tracks and in conveying systems. It is a case of taking the machine about over the floor, instead of bringing everything to it. The machine makes a certain number of moulds while in one spot, and is then moved to some other point, making other similar groups in succession. This system has many points to recommend it. But whether flasks and sand shall be brought to the machine, or the machine taken to these, is a de-

tail on which none but general rules can be laid down, because every foundry must needs be a law unto itself.

In the first place, only the lighter machines are made portable. There is no question of portability, therefore, in the case of the heavy ones. The flasks and sand must come to these, and the moulds be taken away from them. And in the most highly elaborated systems carrying by labourers is supplanted by some system of conveying. In some British shops an annular ring is suspended from a central post with guys, and carries round the completed moulds. This is termed a circus. The sand and flasks are brought to the machines on trolley tracks. In other shops the completed moulds are laid on double rows of rails adjacent to the machines ready for pouring. These systems are fairly economical, because although the materials are brought by hand, the moulds are not carried far. But they are eclipsed by some of the methods of conveying adopted in a few shops in which the sand and boxes are brought on conveyors and the moulds are carried away by the same means. This represents the most advanced stage of the present time.

Again, the question of fixed *vs.* portable machines is one which must be decided partly by the system of pouring adopted in a foundry. If the method of continuous casting be adopted, there is little advantage in having portable machines. The value of these lies in foundries where pouring is done but once or twice a day, at fixed periods, and in readiness for which a large number of moulds have to be prepared on the floor. Of course, as machine moulding becomes extended, the continuous casting system develops. Facilities for this do not exist in foundries where moulds are made exclusively by hand. In the latter it is difficult to make them fast enough; in the former it is often difficult to pour the moulds as fast as made, and the tapping hole of the cupola has to be left open, the metal running all the while. Another point is that, to mould by hand and cast but once or twice a day, demands an immense stock of boxes and other adjuncts which become cumbersome, so that it is better to cast continually and lessen the floor area required for placing them out.

In laying down and operating moulding machines, the total costs must be compared with the total costs of hand moulding. The expense of the machines is often not so heavy as that of the preparation of the patterns, which for permanent service must be of metal, got up with the utmost precision and finish, properly gated, and kept in good condition. A good and fairly constant volume of work is necessary to pay for these. The employment of unskilled men to operate the machines can be remunerative only when the volume of work is constant. In foundries dealing with general work the moulders can be changed from job to job. Not so the machine hand. If the volume of machine work slackens, the attendant cannot do moulding that requires skill, but must mark time, or be dismissed, or suspended until work returns. The conditions most favourable for machine moulding are those in which a large volume of work of a similar character exists.

The system is, however, of a very elastic character. Having a machine, or machines, in a general shop, it is not necessary that they should be in constant use to produce some economies at least. Plain, unjointed patterns, either of wood or metal, one face of which is flat, can be screwed to plates and a few moulds made. The gain then is a little time saved in sleeking the joint, and in getting a better lift with the machine with less risk of broken sand than can be ensured by withdrawal of the pattern by hand. But merely transferring moulders' work from the floor or bench to the machine does not make any difference in the work of ramming. If this requires a moulder's skill on the floor, it will also require that skill with the machine, because precisely the same knowledge and experience are required in each case. But the machine work will be done cheaper, for reasons already given. But when machine mould-

ing is spoken of, something different from this is generally understood, being applied to work which is constantly done upon machines and in performing which the aid of skilled labour is either dispensed with entirely or reduced to microscopic proportions. The knowledge of a skilled man is necessary to settle details and start the work, after which trained labourers can carry it on.

To sum up, the writer's opinion is that for the average work of by far the largest number of foundries the machines which should be installed are the hand-rammed, stripping plate, portable types. In certain cases, which must be decided from a knowledge of special conditions, the fixed machines and power ramming will be found of service, but they are exceptional. The greatest saving effected in moulding machines lies in the withdrawal of the pattern absolutely perpendicularly, and not in the ramming. The latter must be done with all the same precautions and all the variations in detail of common moulding. But the difference in drawing a pattern by hand and drawing it by machine generally makes the difference between incorrect or accurate dimensions, between a broken mould and an uncertain quantity of mending and an unbroken one. The problems involved in the selection of a moulding machine can, therefore, be determined only by a full knowledge of the conditions which rule in each individual shop.

There is no lack of choice of machines, and some of the older ones are as good as the more recent ones for some classes of work. Every year new types are introduced, indicating a growing appreciation of the methods of machine moulding. Outside these, again, lies the system of making toothed wheels by machine, a class of work by itself. In a few foundries there is little hand work now left.

PNEUMATICS

SOME FACTS AND FIGURES ON COMPRESSED AIR

By Professor J. H. Kinealy, Washington University

PNEUMATICS is really that science which treats of the laws of the behaviour of gases, but we usually restrict the word to that science which treats of the laws of air while in a gaseous state. Of late years we have even gone further, and have, to a certain extent, restricted the word pneumatics to the science which treats of the laws which govern the utilisation of air for the transmission of power.

Air, which surrounds us, and of which there seems to be an almost inexhaustible supply, does not of itself possess any power or energy which we can utilise. It is an inert, dead body, just as much so as a stick or a stone. It can serve only as a transmitter of power or energy; as a means of carrying energy from a source of supply to a point of utilisation, or as a body in which energy may be stored by one machine or drawn from by another.

Energy may be stored in a quantity of air by heating it, or by actually doing work upon it. In either case, however, the total energy in the quantity of air is determined by its temperature, and by nothing else, so long as it remains a gas. A change in the pressure or the volume of the quantity of the air does not in any way affect the energy in it, so long as the temperature remains unchanged. That is, a pound of air at 60° Fahr. and atmospheric pressure has just as much energy, no more and no less, as a pound of air at 60° Fahr. and a pressure of 100 pounds above atmospheric pressure.

The total energy in each of the two pounds of air is exactly the same, but the available energy is very different in the two cases. In a pound of air at atmospheric pressure the available energy is almost zero, as we have no machine by which the energy in it can be utilised; but in the second pound of air the available energy, on account of the high pressure, is quite large, as we can utilise a large quantity of the energy in an ordinary air engine or motor.

In all cases the total energy in a quantity of air depends upon the heat in the air and upon nothing else; but the available energy, the energy which we can use by means of the engine or motor which we have, depends upon the difference between the pressure of the quantity of air and the pressure of the atmosphere. When work is done by a quantity of air drawn from a reservoir the heat of the air is decreased and its temperature falls, unless it receives heat from some external source during the performance of the work. And if no heat is received by the air, the decrease of heat, and, therefore, the fall of temperature also, is exactly proportional to the amount of work done or the energy taken from the air. When a quantity of air is in motion, as is the case of the air of winds or the air issuing from the outlet of a fan, it has a certain amount of energy in virtue of its motion, independent of its temperature or pressure. The energy of a pound of air at a given velocity is no more nor less than the energy which a pound of lead or rocks would have if moving at the same velocity. In the case of winds acting upon windmills, the air has been set in motion

by certain physical forces and made to move with a certain velocity; when it strikes a windmill it acts upon the vanes of the wheel and does a certain amount of work, in virtue of its velocity only.

When energy is stored in air, either by the direct giving of heat to it or by the doing of work on it, there are certain laws according to which the pressure, volume, and temperature of the air change. If one of these,—pressure, volume, or temperature,—changes, then one, at least, of the other two must change. It is possible, however, to keep one constant while the other two undergo a change, or a series of changes.

If the temperature is kept constant during a series of changes in the volume and pressure of a quantity of air, the relation between the volume and pressure at any instant is expressed by what is known as Boyle's law, viz., the product of the volume and pressure of a quantity of air at any one instant is equal to the product of the volume and pressure at any other instant. Another way of stating the same law is:—For a quantity of air kept at a constant temperature, the volume changes inversely as the pressure. The volume may be in any units, although it is usual to express it in cubic feet; the pressure, however, must be absolute pressure or pressure counted from zero, and not the pressure above the atmosphere, as is customary when speaking of the pressure of steam in a boiler. The pressure may be pounds or ounces per square inch or per square foot, but in all cases it must be absolute pressure. The absolute pressure is equal to the pressure as indicated by the pressure gauge, commonly called the gauge pressure, plus the atmospheric pressure; and as the atmospheric pressure may for most engineering work be assumed as 15, or more exactly 14.7, pounds per square inch, the absolute pressure is equal to the gauge pressure, plus 15.

If the pressure remain constant, and the volume and temperature pass through a series of changes, the relation which exists between them during the changes is expressed by a law which is a modification of what is known as Gay Lussac's law, viz.:—When the temperature and volume of a quantity of air be changed under constant pressure, the quotient obtained by dividing the volume at any one instant by the absolute temperature for the same instant is equal to the quotient obtained by dividing the volume at any other instant by the corresponding absolute temperature. This is sometimes stated thus:—The quotient obtained by dividing the volume, at any instant, of a quantity of air kept at a constant pressure, by the absolute temperature at the same instant, is a constant quantity.

The absolute temperature is equal to the sum obtained by adding 461 to the temperature in Fahrenheit degrees. Thus the absolute temperature of air at 60° Fahr. is 461 plus 60, equal 521°.

From this law and Boyle's law we get the following one, which always represents the relation existing between the absolute pressure, volume, and absolute temperature of any quantity of air:—The quotient obtained by dividing the product of the absolute pressure and the volume of a given quantity of air by the absolute temperature is a constant quantity. This constant quantity is equal to 0.37 times the weight, in pounds, of the given quantity of air, when the absolute pressure is in pounds per square inch, the volume in cubic feet, and the absolute temperature is measured on the Fahrenheit scale. This one law contains everything in regard to the changes of volume, pressure or temperature of a quantity of air, and it is one of the most important of all the laws of pneumatics, as upon it all the other laws are really based.

When energy is stored in a quantity of air by the direct application of heat, the temperature of the air rises, and we may at the same time let both the volume and the pressure change, or we may keep one constant and let the other change. If we keep the pressure constant and heat the air, about 0.24 of a unit of heat will be required to raise the temperature of one pound of air 1° Fahr.; while if we keep the volume constant, only about 0.17 of a unit of

heat will be required to raise the temperature of one pound of air 1° Fahr. In other words, the specific heat of air at constant pressure is 1.41 times the specific heat at constant volume.

Suppose that we had one pound of air under atmospheric pressure and at a temperature of 70° Fahr., and that we gave to this air one unit of heat while its pressure remained constant. From what has been said before we are able to determine that the volume occupied by the pound of air at 70° Fahr. is about 13.3 cubic feet, that by the unit of heat its temperature would be raised about 4°, and that its volume at the temperature after the heating, about 74°, would be about 75 per cent. greater than before the heating.

If the air were confined in a cylinder with a movable piston, as soon as the pressure rose above that of the atmosphere plus that necessary to overcome the friction of the piston in the cylinder, the piston would move upwards against the atmosphere and do work. If after the piston has moved up as far as the expansion of the air due to the unit of heat put into it would make it go, we cooled the cylinder and the air in it by means of some cool body, the air would begin to contract, and as soon as the difference between the pressure inside of the cylinder and that of the atmosphere was sufficient to overcome the friction of the piston, the atmospheric pressure would make the piston move downwards, and thus do work. This is exactly the principle employed in the Ericsson hot air engine. There, however, the pressure against which the air is made to expand is the atmospheric pressure plus the pressure necessary to overcome the friction and the resistance due to the load against which the engine is working. The air is heated by being made to come in contact with the walls of an iron cylinder which are kept hot by means of a fire; it is then made to pass into a cooling chamber at the upper part of the heating cylinder, where it is cooled by means of a water jacket.

While the air is being heated it forces the piston up, and while it is being cooled the atmospheric pressure forces the piston down. Heat is transferred from the fire to the water in the cooling jacket, and during this transference a small portion of the heat given to the air by the fire is transformed into work.

If we were to give a unit of heat to a pound of air while keeping its volume constant, we should find that as its temperature increased the pressure would also increase. One unit of heat given to a pound of air at constant pressure would raise the temperature about $1.00 \div 0.17 = 6°$, so that if the temperature of the air were 70° Fahr. before the heating, it would be about 76° after the heating. If the pressure before the heating were atmospheric pressure, zero pounds by the gauge, it would be about 1.1 per cent. greater than atmospheric after the heating. That is, one unit of heat given to one pound of air at a temperature of about 70° Fahr. will increase the pressure of the air about 1.1 per cent. when the volume is kept constant, while the temperature will be increased about 6°. To increase the pressure by 11 per cent. it would be necessary to increase the temperature 60°, while keeping the volume constant. After the pressure of the air has been increased by heating, the vessel containing the air may be connected to an air-engine or motor of some kind and the air allowed to pass into it and be made to do work.

The objection to storing energy in air by giving heat to it is that, as the temperature is always increased, it is impossible to prevent radiation and conduction to neighbouring bodies, and thus the heat becomes dissipated and lost. It pays to put energy in air by direct heating only when the air is to be used to do work immediately after the heating, as in the case in air-engines of the Ericsson type and those places where the air passes through the heater while on its way from a reservoir or tank in which it is at a high pressure to an air motor.

The method commonly adopted, and the best one, too, of storing energy in air is to do work on it, to compress it in an air compressor, so as to increase

its pressure by decreasing its volume. As soon as we attempt to decrease the volume of a quantity of air by doing work upon it its temperature tends to increase, while its pressure also increases. By the increase of temperature the total energy in the air is increased, but after the air leaves the compressor and is stored in a tank or reservoir it will cool until its temperature becomes equal to that of the surrounding air and bodies. Therefore, all of the energy which has been put into the air as heat to increase its temperature will eventually be lost and no benefit will be derived from it. Again, the rise in temperature during the compression of the air in the compressor increases the pressure against which the piston of the compressor must be moved, and hence increases the work which must be done in compressing the air. There are, therefore two reasons for keeping the temperature of the air during compression as nearly constant as possible.

In order to keep the temperature from rising during compression it is necessary to cool the air while in the compressor by means of water sprayed into the air or by means of a water jacket around the air cylinder of the compressor. Spraying water into the air cylinder is objectionable, because of the large amount of moisture which is then introduced into the air, and it is, therefore, seldom done. When the air cylinder is large, and the final pressure of the air is high, it is very difficult to keep the temperature from rising by means of a water jacket, as the surface of the water jacket with which the air comes in contact is very small as compared to the volume of air in the cylinder.

When air is compressed and cooled so that there is no change of temperature during compression, we say that the compression is "isothermal compression," and that the air is compressed isothermally; but when it is compressed in a cylinder through which heat cannot pass, we say that the compression is "adiabatic compression," and that the air is compressed adiabatically. As a matter of fact, however, there is probably no actual machine which compresses isothermally; and since it is impossible to make a cylinder whose walls are not conducting, there can be no adiabatic compression in actual practice. These are simply two theoretical conditions of compression between which all compressors work. Some approach very near to the condition of isothermal compression, while others approach nearer the condition of adiabatic compression.

The work required to compress one pound of air adiabatically from atmospheric pressure and a temperature of 60° Fahr. to a gauge pressure of 90 pounds per square inch is about 1⅓ as much as the work required to compress it isothermally, and this increased work of compression results in absolutely no benefit when using the air, unless the receiver into which the air is compressed, all the pipes through which the air passes from the compressor to the receiver, and all of those from the receiver to the air motor are thoroughly covered by some kind of non-conducting substance. Of course, if the air is to be used in a motor immediately after it is compressed, it may then be somewhat economical to compress it adiabatically; but, as a general rule, it may be stated that it is always uneconomical to compress air adiabatically.

When air is compressed by stages it is compressed partly only in one cylinder, then passed to another and partly compressed in it, and then passed on to still another cylinder and compressed partly again, and so on from one cylinder to another until the desired compression has been attained. If there be one cylinder, the machine is called a one-stage compressor; if two cylinders, a two-stage compressor; if three cylinders, a three-stage compressor, etc., etc. For each stage of the compression there is an air compression cylinder, and the machine is named according to the number of compression cylinders or stages of compression through which the air is passed before reaching the reservoir or tank in which it is stored.

It is customary to have intercoolers

through which the air must pass while going from one compression cylinder to the next higher one. These intercoolers are simply vessels containing a large area of cooling surface by means of which the temperature of the air is reduced from that due to the compression in the cylinder which is left before entering the intercooler to as nearly as possible that of the surrounding air and bodies. Sometimes the cooling surface is the outside surface of a number of tubes through which cool or cold water circulates, and at other times it is the inside surface of a number of tubes which are surrounded by water. In either case, however, the action is exactly the same; heat is taken from the hot air, so that its temperature is reduced as much as possible before entering the next compression cylinder.

It is important that the cooling surface of the intercooler be large, and that the body of air be broken up and sub-divided as much as possible, in order that every particle of it may be brought in contact with the cooling surface and kept there as long as possible.

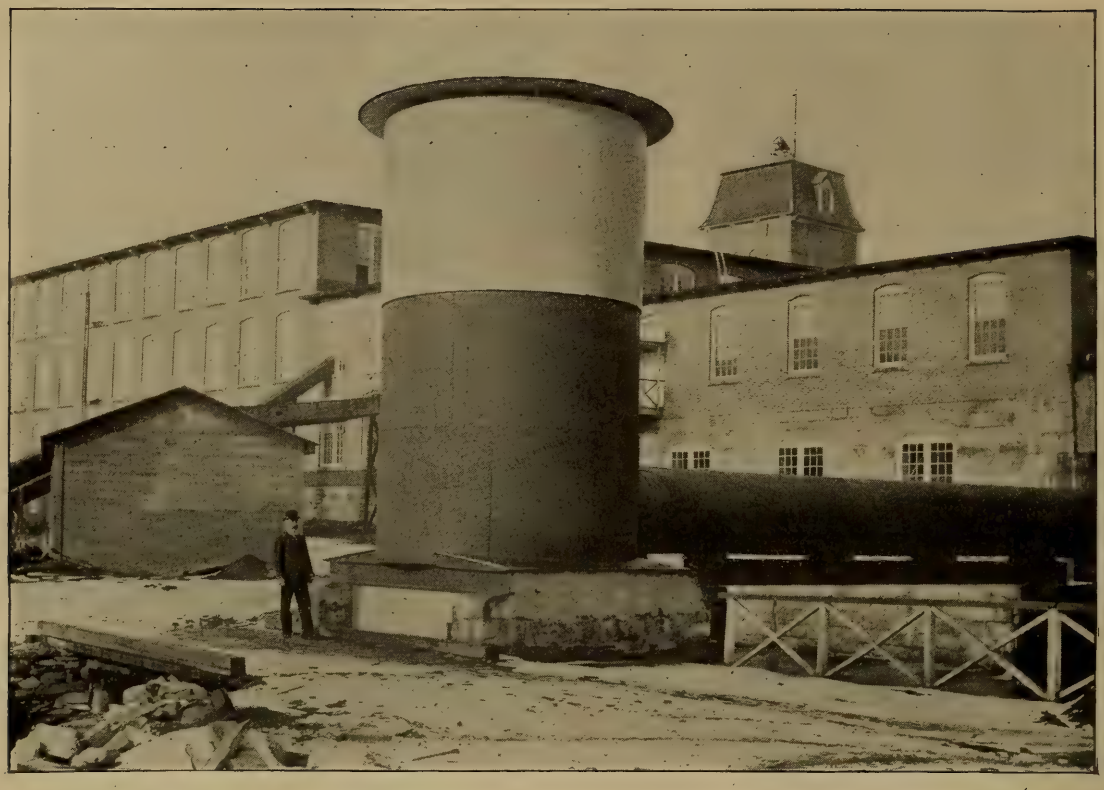
The compound or two-stage compressor is quite common, and its advantage and economy are so generally recognised that now it is considered the compressor to be used for ordinary low pressures of 80 or 100 pounds gauge pressure. For higher pressures, three and four-stage compressors are used. It should be remembered, however, that the efficiency and economy of a multiple-stage compressor depend more upon its intercoolers than anything else, and, therefore, they should be large, properly made and proportioned.

Every air compressor cylinder and every intercooler added to a compressor increase the friction which must be overcome by the driving steam cylinders or steam-engine, and, therefore, increase by a proportionate amount the work which the engine must do; and it is only when the gross saving effected by the addition of an air compression cylinder and an intercooler is greater than the gross loss due to the increased friction and amount of machinery to be run that there is any economy in the addition of the cylinder and intercooler.

In determining this economy the interest on the first cost of the compressor must be included with the running expenses of the compressor. Just as we know that for certain pressures it is more economical to use a compound engine than a triple-expansion engine, and for other pressures it is more economical to use a single-cylinder engine than a compound engine, so it must undoubtedly be true that for some pressures it is more economical to use a single-stage compressor than a two-stage compressor; for other pressures it is more economical to use a compound compressor, and for still other pressures it is more economical to use either a three or four-stage compressor.

Exactly at what pressure a two-stage compressor is more economical than a one-stage compressor, and a three-stage more than a two-stage, and a four-stage more than a three-stage, we do not yet know, because it is only of late years that the use of compressed air has increased to such a degree as to call for very high pressures and to make manufacturers look carefully into the question of multiple-stage compressors and intercoolers. A purely theoretical investigation will show that the loss of energy due to heating the air while compressing adiabatically is, for an initial temperature of 60° Fahr. and a final gauge pressure of 110 pounds, about 38 per cent. for a single-stage compressor, 17 per cent. for a two-stage compressor, and 5 per cent. for a four-stage compressor. If the final pressure were 2000 pounds, the loss would be about 121 per cent. for a single-stage compressor, 45 per cent. for a two-stage compressor, and 20 per cent. for a four-stage compressor.

In 1877 Mr. Frizell, of Boston, read a paper before the Franklin Institute, in which he described an ingenious method of compressing air to any desired pressure by the direct action of the water of a waterfall. This apparatus involves no arrangement with moving parts. The water is made to pass down



THE HYDRAULIC AIR COMPRESSOR AT THE DOMINION COTTON MILLS, MAGOG, QUEBEC

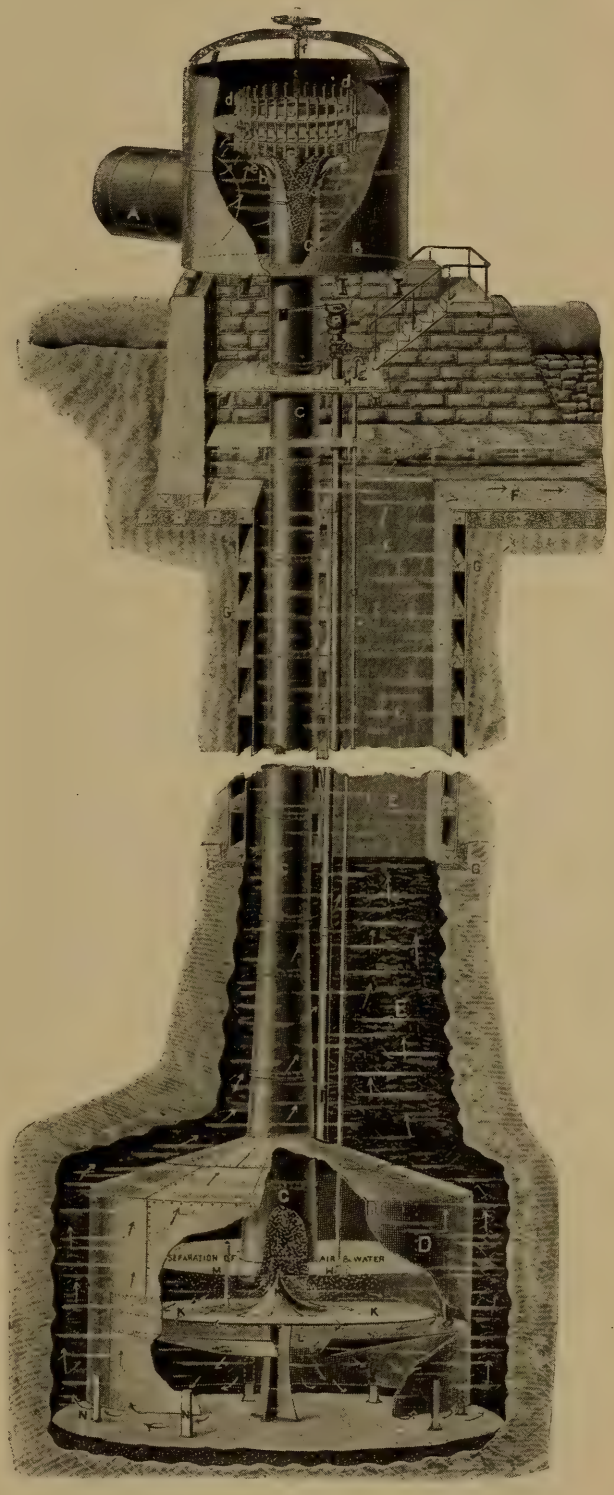
a large vertical tube, and carries particles, or bubbles, of air down with it. At the bottom of this tube there is a separating chamber where the air is separated from the water. The air collects in the upper part of the chamber and the water in the lower part. By means of suitable pipes the compressed air is led off to where it is to be used, and the water is led off into a waste channel or sluice. The pressure to which the air is compressed is entirely independent of the height of the waterfall, and depends only upon the length of the tube down which the water and air fall. By digging a well of the proper depth this tube may be made as long as desired; it must be approximately 2.3 feet for each pound of gauge pressure. An apparatus of this kind was installed in Canada, a few years ago to supply compressed air for running a cotton mill. The superintendent of the mill wrote to me about two years after the plant had been installed and said that it gave entire satisfaction, and had been furnishing compressed air enough to run the mill ever since its installation. The compression by such an apparatus must, of course, be quite isothermal, but the air must be saturated with moisture, and would, therefore, be objectionable in many cases. On account of the depth of the well required for the compressor pipe, such an apparatus could not be used for very high pressures.

[It seems interesting to give here the sectional view of an hydraulic air compressor of the kind referred to by Professor Kinealy, and also the illustration above of the particular compressor, referred to, installed at the Dominion Cotton Mills, at Magog, Quebec, Canada. It is there operating under a 20-foot head of water, and supplies compressed air for six engines developing about 100 H. P. This plant, it is stated, has been in operation continuously, day and night, for several years, with entire satisfaction.

The working of the compressor will be understood from the sectional view. The water is conveyed to the tank *B* through the penstock *A*, where it rises to the same level as the source of supply. In order to start the compressor the head piece *J* must be lowered by

means of the hand-wheel *f*, so that the water may be admitted between the two castings *b* and *c*. The supply of water to the compressor is governed by the depth to which the head piece is lowered into the water. The water enters the compressing pipe between the two castings *b* and *a*, passing among, and in the same direction as, the small air inlet pipes. A partial vacuum is created by the water at the ends of these small pipes, and hence atmospheric pressure drives the air into the water in innumerable small bubbles, which are carried by the water down the compressing pipe *C*. During their downward course with the water the bubbles are compressed, the final pressure being proportional to the column of return water in the shaft *E* and tailrace *F*. When they reach the disperser *K* their direction of motion is changed, along with that of the water, from the vertical to the horizontal. The disperser directs the mixed water and air towards the circumference of the separating chamber *D*. Its direction is again changed towards the centre by the apron *L*. From there the water flows outwardly, and, free of air, passes under the lower edge of the separating chamber. During this process of travel in the separating tank, which is slow compared with the motion in the compressing pipe *C*, the air by its buoyancy has been rising through the water and pipes *M*, *M*, from under the apron and disperser, to the top of the air chamber *D*, where it displaces the water. The air in the chamber is kept under a nearly uniform pressure by the weight of the ascending water in the shaft and tailrace. The air is conveyed through the main *I* up the shaft to an automatic regulating valve, and from there it is led away for use as required. When sufficient air has accumulated in the separating chamber to displace the water almost to the lower end of the compressing pipe it escapes through the blow-off pipe *H*.—THE EDITOR.]

After a quantity of air has been compressed so that its pressure is greater than atmospheric pressure we have a source of energy from which we can draw at any time to do various kinds of work. The number of places in which compressed air is used, and the purpose



VERTICAL SECTION OF THE MAGOG COMPRESSOR

for which it is used, are very great and varied. Its use is constantly growing, and there are very few industries or manufacturing establishments in which it

is not now employed. The use of electricity as a means of transmitting power, instead of diminishing the use of compressed air, has tended to increase it.

Compressed air has an advantage over electricity in that it is perfectly safe and harmless; there is no danger of getting shocked or of a leak setting fire to buildings or goods; and, further, the air having been compressed, it may be drawn upon at any time, without regard to whether the compressor is running or is not running, but is always ready for service as long as its pressure exceeds that of the atmosphere. A quantity of air may be compressed and then the compressor may be stopped until that air has been used; but with electricity the engine and dynamo must be kept running during the entire time when it is likely that electricity will be needed, unless a system of storage batteries be installed. These, however, are usually too expensive for the average manufacturer.

The loss due to leakage of air through the pipes by which it is transmitted from the compressor to where it is used is so small in a properly put-up system of piping that it may be neglected entirely. The main loss is probably due to the friction, but even that may be made exceedingly small by putting in pipes of proper size. Someone has said that the friction of air in the pipes does not really mean a loss because the energy used to overcome the friction is converted into heat, which raises the temperature of the air, and is given up again when the air is used to do work. In fact, however, this heat is usually lost in the surrounding air.

It is extremely difficult to get reliable data upon which to base a comparison of the cost of using electricity with that of compressed air, because of the different ways in which they are installed and used. Electric systems are always installed with great care, and are always properly installed; this is seen to by the insurance companies and by the erectors and builders of electric machinery; but compressed air plants are usually installed in any and every way. The manufacturer buys the compressor and then puts up his line of piping as he pleases, often entailing great loss on account of small pipes and improperly made bends and joints.

Experience has shown that, in order to transmit electricity with economy, it must be transmitted at high electrical pressure and reduced at the motor; so, too, in order to transmit air with economy, it should be transmitted under high pressures. The higher the pressure the less the space which will be occupied by a quantity of air and the more efficiently can it be used. I am of the opinion that one of the reasons, and, in fact, the main reason, why compressed air at high pressures has not been experimented with more in connection with automobiles of different sizes and kinds is that there are so few plants in the country where air can be compressed at all, to say nothing of doing it economically, to pressures in the neighbourhood of 1000 to 1500 pounds per square inch.

One pound of air compressed to 1000 pounds per square inch, and at a temperature of about 60° Fahr., would occupy the volume of about one and one-half gallons, and if heated by a heater before passing into a motor could be made to develop a little over one horse-power for a little more than three minutes. The heat which it would be necessary to give to the air while being used would be about 150 units, or the heat which would be given off by one and one-half pounds of water cooling 100° Fahr.

The motors in which air is generally used for generating power are simply ordinary slide-valve engines in which air instead of steam is employed. When, however, the air is used expansively, as it must always be when under a high pressure, it becomes absolutely necessary to heat the air by a reheater, as it is called, just before it enters the motor. If this is not done the temperature will fall very low, and there will be a deposit of frost or ice on the pipes and cylinders of the engine.

If there is much moisture in the air, there may also be a choking up of the exhaust pipe by the ice or snow formed

during the expansion. For ordinary low pressures, such as are in general use, and when the air is not expanded very much in the motor, it has been shown by experience that there is no danger of the exhaust freezing up. Of course, if the air has been deprived of its moisture during or after the compression, there is no danger at any time of a freezing up of the exhaust or a deposit of snow or ice in the cylinder of the motor.

There are no fields, probably, where the use of compressed air is being watched with more attention than those of dispatch and traction, where cars, large for passengers and freight, and small for mail and light parcels, are propelled by air. Pneumatic dispatch is successfully employed for the transmission of letters, papers, money or small parcels from point to point by means of small carriages or carriers, as they are called, which are propelled by the pressure of air compressed to a gauge pressure of between five and fifteen pounds, or by the pressure of the atmosphere acting against a partial vacuum created in front of the carriers.

The first pneumatic dispatch system was installed in 1853 in London. The tube was 1½ inches in diameter and only 220 yards long. Since then pneumatic dispatch tubes have been installed in many European cities, principally for the carrying of letters and telegrams from parts of a building to other parts of the same building, or from one part of a city to other parts.

About 1875 or 1876 the Western Union Telegraph Company installed a pneumatic dispatch system in New York to dispatch its telegrams from one part of the city to the other, as they found that it was quicker to send telegrams in this way than to telegraph them. Up to 1893 the diameter of the tubes used for pneumatic dispatch varied from 1½ to 3 inches, there being none larger than 3 inches.

In 1893 a pneumatic dispatch plant was installed in Philadelphia for carrying mail back and forth between the main postoffice and the sub-postoffice. There are two tubes in this system, each 6 inches in internal diameter, and about 3000 feet long. It takes about one minute for the carrier to make the trip from one station to the other. The system uses about 800 cubic feet of free air per minute, which is compressed to a pressure of about seven pounds above the atmosphere. About 1897 an 8-inch dispatch tube a little more than three-quarters of a mile long was laid in Boston, and later, 8-inch tubes were laid for pneumatic dispatch systems in New York and in Philadelphia.

Two or three attempts have been made to adapt the pneumatic dispatch system to the carrying of passengers, but all have failed. In 1864 F. A. Rammell constructed a short railroad about 1800 feet long, which was really a pneumatic dispatch for passengers. It was constructed on the grounds of the Crystal Palace at Sydenham, England. Cars holding about thirty passengers were forced through a tunnel about 10 feet high and 6 feet wide by means of compressed air working at a pressure above the atmosphere of about 0.16 of a pound per square inch.

About 1840 an atmospheric railroad was constructed in Ireland from Kingstown to Dalkey, a distance of about one and one-half miles. The carriages or cars of this road ran on rails laid as for the ordinary steam railroad, and were propelled by means of a long piston which moved in a tube beneath the track. This piston was connected to the driving car by a suitable lever or arm, which projected up through a slot in the tube in which the piston moved. This slot was kept closed in front of the piston by means of a leather flap which extended over and lay flat on top of it. By means of an air pump, connected by suitable pipes to the ends of the central tube in which the piston moved, a partial vacuum was created in front of the piston, and the atmospheric pressure at its back forced it along in the tube. The central tube was 15 inches in diameter, and the piston was attached to a long piston-rod carried by four wheels which ran in the tube. The piston projected some distance ahead of

the car to which it was attached. The leather flap valve was opened for the passage along the slot of the arm which connected the piston-rod to the carriage above by two of the wheels which supported the piston-rod. These two wheels, one of which was in front of the arm and the other immediately behind it, were somewhat greater in diameter than 15 inches, so that they forced the flap valve up as they ran along. The flap valve was closed by a wheel which ran along on top of it, and which was attached to the rear end of the carriage to which the piston was attached. It is evident that by this arrangement of air pump, piston, wheels, etc., a partial vacuum could always be maintained in front of the piston and atmospheric pressure behind it, and the difference between the two pressures would tend to move the piston along in the tube. As the piston moved, the car to which it was attached also moved, and as it moved it pulled along the cars which were attached to it.

Two reports were made on this railroad, one by Mallet to the French Government, and the other by Robert Stephenson to the directors of the Chester & Holyhead Railway, of England. Mallet's report was made in January, 1844, and Stephenson's in April, 1844. Mallet, after a discussion of the atmospheric road and its working, in which he speaks very favourably of the road, says:—

"The question is not yet in so advanced a state, but it is sufficient that the success of such application appears probably to render the system worthy of special attention on the part of the administration. Admitting the equality of the two systems in the expense of construction, the atmospheric has an incontestable advantage over the locomotive system in that of working. I have sought to estimate that advantage, but its existence was self-evident from the absences of those enormous masses, the locomotive and tender, which frequently form the third part, sometimes half of the weight to be moved, and the movements of which on comparatively slight inclinations absorb the whole power produced." Stephenson made a most exhaustive investigation of the subject, as it appears that the directors of the Chester & Holyhead Railway were considering the advisability of adopting the atmospheric system on their railway. In the first part of his report Stephenson said:—

" * * * I also felt strongly that whatever might be my opinion, whether favourable or unfavourable, the final destiny of the invention was not in my hands; and that if it were really calculated to produce the remarkable results which had been stated, nothing could stop its universal application to railways. On the other hand, I saw that if the principles of the invention were not soundly based, I should be incurring a most serious responsibility in recommending its application to the Chester & Holyhead Railway, extending over a distance of eighty-five miles."

He gave seven items of the conclusions to which his investigations led him. The first, however, covered almost everything. It was:—

"That the atmospheric system is not an economical mode of transmitting power, and inferior in this respect both to locomotive engines and stationary engines with ropes."

When he spoke of stationary engines with ropes, Stephenson had in mind the old system in which the cars to be hauled were attached to the end of a long rope and pulled along by winding the rope on a drum by means of a stationary engine.

Of late years a great deal of experimenting has been done with various systems of pneumatic traction with a view to perfecting a system for use on street, surface, and overhead railways. In most of the systems which have been tried the principle is about the same. The motor car is provided with strong steel tanks in which a supply of air sufficient for one or more trips is stored under a high pressure, usually in the neighbourhood of 2000 or 2500 pounds per square inch. This air is used to run a motor or engine carried by the car, and enables it to haul along a certain number of trailers, depending upon

the power of the motor and the number of people in each trailer.

A good system of compressed air traction would have the advantage of having little or no fire or smoke on the motor, and each motor would be run entirely independent of all the others. A breakdown in any one motor would in no way affect the running abilities of the others; and as each car would carry its own motive power, it would be difficult to interfere with the running of all the cars at one time, provided there were duplicate compressors.

ALTERNATING-CURRENT POWER WORK

By T. P. Gaylord

POLYPHASE generators may be divided into three general classes, depending upon the nature of their revolving element, viz.:—

1st. Revolving armature generators.

2d. Revolving field generators.

3d. Induction type generators.

The induction type generator appeared several years ago as a kind of electrical fad, but developed so many inherent defects that it is now being abandoned. The revolving armature and revolving field generators each have their place, depending upon the class of service required. The stationary armature machine avoids the use of collector rings, which are objectionable only in case of very large current-carrying capacity generators. Somewhat better insulation can be maintained on the stationary coils, which makes this type of machine better adapted to high voltages.

The revolving armature machine, in moderate sizes, will give slightly better regulation and efficiency than the revolving field machine, due to the fact that the armature circuit is shorter, giving less current loss and less self-induction. The difference, however, between the revolving field generator and the revolving armature machine is slight.

One of the important problems met with in connection with the design and operation of polyphase generators is that of multiple operation. For simplicity and flexibility of operation it is desirable to have all the generators of one station capable of being connected together electrically and feeding into a common system of distribution. Successful multiple operation depends almost entirely upon the speed characteristics of the prime mover. Uniform angular rotation is essential, and the different engines driving generators in multiple must have a speed regulation such that they will deliver power to their respective generators (depending upon their capacity) in proportion to the total load. In case of water-wheel drives, the problem is a very simple one, and generators so driven are paralleled without difficulty. Where steam-engines are used as prime movers the responsibility at once falls upon the engine builder. It is customary for the generator builder to indicate what variation from uniform angular motion may be permitted for any given installation, and with this information the engine builder can supply proper fly-wheel capacity and governing devices necessary for the successful operation of the generators in multiple.

Generators of both the revolving field and revolving armature type are manufactured suitable for direct connection to nearly all classes of engines and

water-wheels. Any desired voltage may be obtained up to 6600, or even 12,000 volts, direct from the generator; but it is usually considered better practice, where high voltages are necessary, to generate at a nominal voltage of 1100 or 2200, and step-up by means of transformers. By this means the station apparatus can be better protected from lightning, as the transformer is capable of being better insulated than the windings of a generator.

Transformers, for use in connection with power transmission systems, are made in two distinct types,—the oil-insulated or self cooling type, and the air-blast transformer. With the oil-insulated type no auxiliary apparatus, in the form of a blower, is necessary; but there are some installations where the storing of large quantities of oil is considered objectionable, on account of the supposed fire risk, and in such places the air-blast transformer is furnished. However, with a proper transformer oil, having a flash test of 350 degrees Fahr., there is little or no danger from fire. Such an oil is regularly upon the market, and should always be used for transformers installed within doors.

For general power purposes the alternating current, applied direct to motors, meets all requirements; but there are some special classes of work, notably street railway operation, which, for the present at least, in nearly all cases require direct current. The induction motor, for traction purposes, has, however, recently received considerable attention. While it may not fulfill street railway conditions as well as the series direct-current motor, it would be unfair to infer that the induction motor is in any way inferior to the direct-current. In considering this question, one should not make the comparison simply between the alternating current and direct current, but rather between a motor of automatically varying field strength and one of constant field strength. The series motor, representing the first class, is particularly well suited to frequent starting and accelerating railway loads, while the direct-current shunt motor or the alternating-current induction motor, representing the second class, are not as well suited for this service. With interurban roads, where starting and accelerating is relatively infrequent, and, therefore, an unimportant part of the work, the series motor may not present the same advantage over the induction motor.

In a general system of polyphase power distribution, where it is necessary to use direct current, the alternating current is transformed to direct current by means of the rotary converter. But this transforming of alternating into direct current is only one of several uses for which the converter may be employed. It may be driven mechanically and deliver either alternating or direct current, or both. In stations combining both lighting and railway work it is often installed as a connecting link between the two systems, operating either from the alternating or the direct-current generator.

Rotary converters, for delivering direct current, are usually provided with a small induction motor, mounted upon the rotary shaft, for the purpose of bringing it into synchronism with the generator feeding the circuit. They may, however, be started by opening the field circuit and throwing alternate current directly on the armature; but this method, if applied to a rotary large in comparison with the generator, results in pulling a heavy momentary load from the station. Another method of starting is by means of direct current and a starting rheostat, where a constant source of direct current can be obtained.

Where rotaries are to run from direct current and feed an alternating-current system they should be excited from a small generator, mounted on the rotary shaft, and subject to the same speed variation which takes place in the rotary. A short-circuit or a sudden overload on the alternating-current side of the rotary tends to demagnetise the fields, and, consequently, increase the speed of the rotary converter. With the direct-connected exciter, the rotary magnetic field would strengthen as the speed increased, and any tendency

which the rotary might have to run away would be thus obviated.

The rotary, in trying to follow the generator speed, sometimes gets into an oscillation or pendular motion relative to the generating system. This effect is generally known as "pumping," and if allowed to develop to any considerable extent, may cause serious trouble. To prevent this copper shoes are placed on the pole faces. These act as a brake to this oscillating motion, the braking action varying with the amount of oscillation. The corrective action is thus greatest with the greatest "pumping," and with a generating system which has considerable angular variation in the driving power there will be a braking or damping action at all times. This also applies to synchronous motors

One of the most attractive features of the alternating-current power system is the induction type motor. While the synchronous motor has received considerable attention and has been used with success in many cases, yet it does not meet the varied conditions of general power service. The polyphase synchronous motor can be made self-starting, but its torque at starting is very small, and it is, therefore, not suited to a great majority of installations. Its field must be excited by direct current, making usually an auxiliary piece of apparatus to accompany the motor. Furthermore, to secure the best results, the field charge should be varied as the load changes, which means constant attention under usual conditions. Its efficiency, under ideal conditions, is slightly greater than that of the induction motor, but these conditions are so seldom attained in practice that little or nothing can be gained in this respect.

The induction type motor has none of the objectionable features mentioned above. In the standard form there are no electrical connections to moving parts, and no adjustments to make. For this reason it is the most nearly "fool-proof" motor ever designed.

The starting torque of the induction motor does not differ materially from that of the direct-current motor. Within certain limits speed regulation and starting torque are factors which are diametrically opposed to each other. In the standard induction motor, two and one-half times full load torque can easily be obtained, and in the large sizes of 200 to 500 H. P. capacity three and one-half to five times full load torque can be obtained without sacrificing speed regulation to any appreciable extent. In what may be termed the constant-speed motor the resistance of the secondary, or revolving element, is made as low as possible. This gives a speed curve which falls off but little from no load to full load, and brings the maximum torque at about two-thirds synchronous speed. This maximum torque is usually several times full-load torque, making the motor capable of carrying enormous overloads before breaking down, a feature which is very desirable in many classes of work.

Many who have not closely followed the development of the alternating-current power business are of the opinion that the induction motor is not suitable for variable speed work, but it may be stated positively that there are but few conditions requiring a variable speed motor that cannot be met successfully by means of an induction motor, properly designed.

There are two types of variable speed induction motors,—one in which the speed changes are accomplished by varying the voltage applied to the primary, while in the other the speed changes are made by varying the resistance of the secondary. In the first type the design and construction are similar to the standard speed motor, except that the secondary resistance is made greater, thereby bringing the maximum torque at zero speed; or, in other words, at the point of starting. In this case the speed curve falls off rapidly as the torque increases. The torque for all speeds varies approximately as the square of the voltage applied to the primary; so, by applying proper voltage, any desired torque, from zero to maximum, may be obtained.

The induction motor is not limited

in the voltage of the supply current in the same way that the direct-current motor is limited. In the latter the voltage for which commutators can be constructed, and at which they can be properly operated, is a matter of the greatest importance. These considerations, of course, do not apply to the induction motor, and, if the matter of insulation be neglected, the general statement may be made that the motor can be wound for any voltage, the number of turns being increased in proportion as the voltage is increased. It is obvious, however, that the increased number of turns requires a greater amount of insulation; hence, the motor must be of larger size, and its efficiency must be necessarily somewhat reduced.

On the other hand, the voltage of the supply circuit must not be so great as to become dangerous, either to property by increasing the fire risk, or to persons. It is found that almost all cases are satisfactorily met by a voltage of either 200 or 400, and these voltages have, therefore, been made standard. A convenience also arises in the facility and interchangeability of transformers for supplying the various standard voltages of 100, 200, and 400 volts. Motors of only a few horse-power cannot be advantageously wound for higher voltages. Larger motors can be readily wound for higher voltages, and motors of 40 or 50 H. P. are frequently wound for 1000 or 2000 volts, although the construction is not as desirable as that for lower voltages.

Direct-current motors are usually wound for 110 or 220 volts for general service, and in exceptional cases where a higher voltage is admissible, 500 volts are employed. The construction of the induction motor being more advantageous for higher voltages than those for the direct-current motor, it follows that higher voltages may be safely employed. The 200 and 400-volt induction motors are in general use where 110 or 220 volts would be employed if direct-current motors had been used. For higher voltages it will often be found that the conditions which would make 500 volts direct current allowable will permit the use of 1000 volts for alternating-current motors. In this way a decided advantage is given to the alternating-current motor in the point of economy in the conductors for supplying the current.

For power work only, the three-phase system would be selected, as it would effect a saving of 25 per cent. in line copper. Where light and power work are combined, the two-phase system would give the best results.

The question of frequency is important. If the plant contemplates both arc and incandescent lighting, combined with power, a frequency of 7200 alternations per minute would be selected, inasmuch as arc lamps do not operate very successfully on frequencies much lower than this. Incandescent lighting can be done satisfactorily on a frequency as low as 3600 alternations per minute, and for shop work and general outside lighting 3000 alternations will give satisfactory results.

The number of alternating-current power installations recently made, using induction motors of both standard and variable speed types, has been large and entirely successful. The results obtained by the use of this apparatus have been gratifying, both to the manufacturer and to the purchaser, and insure a broad field for alternating-current power work.

ZINC MINING IN THE UNITED STATES

THE JOPLIN MINERAL DISTRICT IN MISSOURI

By Day Allen Willey

WHAT is known as the Joplin mining region in Southwestern Missouri has formed a very interesting study to geologists and mining engineers since it became known that lead and zinc,—zinc especially,—exist in it in a variety of formations and in extensive deposits. The natural surface of the region between Joplin and Webb City is similar to that of many agricultural sections in the Western and Middle States, being rolling land on which staple grain and vegetables, also apples and other orchard fruits, are raised.

At Webb City the topography abruptly changes to limestone exposures and the barren rock formation which is usually the accompaniment of a mineral territory. In some places near Joplin ore has been found two or three feet below the roots of vegetation, so that only the pick and spade were necessary to uncover the pockets containing it. In other parts the drill has penetrated 150 feet of rock before reaching the mineral in paying quantities, while in one instance a boring was made to the depth of 2000 feet without finding a trace of it.

The district which extends sixty miles from east to west and thirty miles from north to south is included in the counties of Jasper, Lawrence, Newton, Barry, and Greene, and a few miles of Cherokee County, in the State of Kansas. The section between Joplin and Galena,—nine miles,—contains most of the larger workings. Throughout the district, however, mining is conducted on a more or less important scale, and the visitor can see every form of treatment, from the hand jig to the modern concentration plant. While the territory embraces about 1000 square miles, only a comparatively small portion has

A GENERAL VIEW OF THE MINING DISTRICT NEAR WEBB CITY, MISSOURI

ON A FARM NEAR JOPLIN

A TYPICAL SHAFT AND MILLING PLANT

thus far been exploited. The extent of the deposits between Joplin and Galena and their accessibility have caused this section to become the centre of the principal activity, and it is estimated that fully 7500 men are employed in connection with the 600 shafts and 800 hand jigs are in operation in this part of the country alone.

The Ozark uplift in which the lead and zinc of the Joplin district are found is well known as one of the most peculiar geological formations in the world, and here its peculiarities are very marked. Layers of flint and limestone containing the ore have been discovered ranging from two to three inches to 300 feet in thickness. The zinc usually lies beneath the lead in openings in the rock, the specimens of ore varying in

size from very small crystals and minute particles to boulders of ore of an estimated weight of twenty and twenty-five tons. The rock formation is broken into fissures of every conceivable size throughout the region, and is of such irregularity that it is impossible to determine the location of the larger deposits except by actual penetration of every portion, for a few feet away from a deposit containing a few pounds may exist masses representing a thousand tons. Again, between one bed and another there may be a space of a hundred feet or of half a mile.

The same conditions prevail in the matter of depth of the ore. While a very small amount has thus far been extracted beyond a depth of 200 feet, the opinion is generally held that large quantities of ore can be secured between 300 and 500 feet should it become necessary to sink the shafts to this depth. In the vicinity of Galena most of the workings are less than 100 feet below the surface. Near Joplin they average from 150 to 250 feet. Although the lead is usually found above the zinc, a number of mines have been opened in which the former was found in paying quantities at a depth of from 100 to 130 feet. At a mine near Galena the shaft struck zinc 100 feet below the surface. After it had been taken out, further examination showed the existence of a large deposit of lead ore 100 feet below the formation containing the zinc.

The most abundant ore taken out of this district is the zinc-blende which is found in clay and sand, as well as in the flint and limestone. The other varieties consist of galena, pyrite, marcasite, and chalcopyrite. The miners classify it into "Jack," "Rosin Jack," and "Black Jack," distinguishing it by colour. Analyses of the zinc ore taken from all parts of the region show from 60 to 66 per cent. of pure metal, and in some cases 66 per cent. with 33 per cent. of sulphur.

In conducting the mining operations throughout the territory, the general plan has been to divide a property into acre lots. These are leased to a company or individual who, in turn, divides his holdings into sections 200 feet square and sub-leases. He pays 10 per cent. of the product to the owner as royalty and takes 20 per cent. from his mining tenant. Consequently the latter receives 80 per cent. of the value of the ore for himself, out of which he must pay for labour and material. The first lessee usually arranges to drain the mines.

Within the last two or three years several companies have been formed to take a tract of 50 or 100 acres and mine it on a large scale, but the old-time method prevails in much of the territory,—of leasing and sub-leasing. As soon as a lot is secured, the miner usually arranges with the owner of a drilling outfit to make a certain number of openings at different depths to determine the locality and thickness of the ore deposits, if any. Some of the drilling outfits are operated by the steam-engine which draws them from place to place, while others are similar to the rigs used in the oil fields, being transported from place to place in vehicles. In certain localities where ore has been found close to the surface, test shafts have been sunk to the beds and the use of the drill has been unnecessary, but these instances are very few. It has been found that from 150 to 250 feet a week can be bored in the limestone formation at a cost of from $200 to $300 (£40 to £60). In a few instances the cost has been greater, owing to the hardness of the strata encountered.

The mining operations in the Joplin district are varied in character. In places where the ore is found with only a few feet of rock between it and the surface it is frequently unnecessary, as already mentioned, to use even a drill. The miner works a hole into one of the fissures with his bar, inserts his charge of powder, and lays bare a considerable tonnage by a single blast. Where it is necessary to sink a shaft, the opening is made also into the ore bed to a distance of from 10 to 25 feet, according to estimated dimensions of the deposit. Then a lateral opening, or drift, is started with an average width of 25 to

CENTRE CREEK MINE. THIS HAS YIELDED ORE VALUED AT $4,000,000 (£800,000) SINCE IT BEGAN OPERATIONS

30 feet, the ore being extracted from the top to the floor of the drift. This chamber exhausted, the shaft is again sunk, further exposing the bed, so that the operation can be repeated.

The method of removing the ore depends entirely upon the character of the formation. In some workings it can be mined to a considerable extent with pick and shovel. In others the work is attended with as much difficulty as in an anthracite coal mine, and a liberal use of explosives is necessary to loosen the material. The blasts are arranged as in coal mining, black powder being generally used. The extent of the fissures, however, is such that special care must be taken in propping. In operating in deposits of looser ores, a framework of timber is set into the sides and over the top of the mass to be extracted, by making incisions and driving the timbering into them. Thus the upper strata are supported while the ore is removed. This excavation made, another framework is inserted and the process continued, if necessary to the end of the drift. When completed, a foundation of timbers is laid on the top of the ore remaining to be cut out. The props which have been placed in position are then blown to pieces by exploding dynamite cartridges in them. The mass of rock and earth, loosened by the falling props, falls upon the flooring, forming a protection under which the ore below can be extracted by another drift. In this manner the material of the roof is converted from a danger into a safeguard.

The lateral work in the mines in the Joplin district seldom extends over 300 feet from the main shaft. In some mines the drifts are abandoned at a distance of 150 feet from the shaft, simply because it is more economical to sink a new shaft, 100 or 150 feet as required, and start a new series of chambers, than to haul the material from long drifts to the foot of the opening, even if a tramway is built and hand or mule cars are used for transportation. In some of the mines, in fact, the miners still trundle the ore in barrows to the foot of the shaft as fast as it is extracted and dump it into buckets, in which it is raised to the surface by winding the hoisting rope around a drum turned by animal power. This method, however, has become obsolete in most of the workings, although the present hoisting appliances are very simple in character,

Engines of from 10 to 25 H. P. answer for most of the hoisting plants. In the largest mines the rope and bucket are used, the load ranging from 200 to 1000 pounds, the average being about 500 pounds. As fast as filled from the mine cars, the buckets are raised and dumped either into the elevator of the concentrating works or into a surface tram or railway car.

Hand-cleaning or jigging is carried on to a considerable extent throughout the district, but it is confined almost exclusively to small operations. The material raised from the shaft is thrown into a sieve placed in a box through which a stream of water is turned. The sieve, which is 2 feet by 5 feet, and 8 inches deep, is attached to a pole 16 feet long. By rapidly jerking the pole up and down with the hand the contents of the sieve are so washed that a considerable portion of the impurities is separated from the ore proper. The modern milling plant, however, is far more economical in operation, and is rapidly succeeding the hand method.

The mill most favoured in the Joplin region is what is known as the 100-ton type, separating, crushing, and cleaning this quantity in ten hours. In operating it, the ore is elevated to a crusher from the mine entrance, usually by an endless conveyor. Running through the crushing rolls, it is taken up by another elevator and passed to a pair of cylindrical revolving screens which separate it into what are termed oversize and undersize. The oversize is carried to another set of crushing rolls for reduction. The material is again graded into two sizes, the larger going into what are known as the roughing jigs and the smaller into the sand jigs with the undersize. Connected with the roughing jigs is another set of crushers which takes up the middlings and tailings, which also pass into the sand jigs. After the jigging process, an endless belt conveys the tailings to the dumping ground, the concentrates being carried to storage bins. Some of the more modern plants have sludge mills for further extracting the "jack" from the tailings. Sand and water are used, by which the material is separated, the "jack" being caught in a "clean-up" box. It is calculated that fully 90 per cent. of the "jack" left in the tailings of the ordinary concentrator can thus be extracted.

MINING PLANTS IN THE JOPLIN DISTRICT

Despite the merging of several of the mines and smelters under one ownership, most of the product of this territory is sold on the spot to buyers for reduction companies,—a custom that

has prevailed in the region since the beginning of mining ore on an extensive scale. The Belgian and Welsh companies depending partly on this district for their raw material have resident buyers who visit the various shafts and purchase in the open market by the assay method, as do the American agents. The material for export is packed in sacks.

The local smelting industry, however, has assumed such proportions that the 12,500 retorts in the works in Southeast Kansas alone take two thirds of the zinc output. Plants in Illinois and Indiana also depend on this field for the bulk of their ore, and great as has been the increase in tonnage, it has not been sufficient in the last two years to meet the requirements of the smelters. With the discovery of natural gas in Kansas the local reduction companies are on a par with those in Illinois and Indiana, having the choice of coal or gas as fuel.

The remarkable development of the Joplin district is indicated by comparative statistics. Prospected first for its lead deposits, until 1874 mining was confined to this metal, the other ore being considered valueless. Lead was first obtained for commercial purposes in 1848, but only 25,000 tons were mined up to 1860. From 1870 to 1880 the production aggregated 62,000 tons, and reached its climax in the decade between 1880 and 1890 with 124,000 tons, doubling the tonnage of the previous period.

The erection of a zinc smelter near Potosi, Missouri, to reduce the ore found in that vicinity, probably aroused interest in the deposits hitherto considered worthless by the lead miners of the Southwest section. A test shipment of a few hundred pounds, made in 1871 to the Matthiesen smelter at La Salle, Illinois, resulted in a price of $3 (12 sh.) per ton being placed on it. The company, however, made a later offer of $10 (£2) per ton, and the extracting of zinc with the lead was taken up systematically. The output increased from 1000 tons in 1873 to 27,500 tons in 1880, 115,000 tons in 1890, and 139,000 tons in 1895, while the estimate for 1901 is 250,000 tons, slightly less than 1899, when the production reached 256,000 tons, the greatest in the history of the field. On the other hand, lead ore production has declined to about 25,000 tons,—not from exhaustion of deposits, but by reason of the greater profit of zinc mining. The value of the zinc ore output of the district has, of course, greatly varied, according to market fluctuations, but it increased from $9000 in 1873 to $450,000 in 1880 and $2,600,000 in 1890. For 1901 the value is estimated at between $8,500,000 and $9,000,000, The lead output will represent about $750,000, or 80 per cent. additional. The industry supports a population of 250,000 in the vicinity of Joplin, Webb City, and Galena alone, and supplies 450 milling plants besides the hand operators.

It is calculated that both zinc and lead can be secured and prepared for reduction in this region at a lower cost than elsewhere in the world. The assertion is based on the average price of material, the cost of labour, and the economy in the mechanical processes, notwithstanding the fact that crude and antiquated methods are still followed in many of the operations. The cost of drilling has already been referred to. An outfit can be purchased for $1200 to $1500 and operated for $60 a week, including wages, fuel, and-all incidentals. The cost of mining depends on the formation, but in many of the workings ranges from forty to fifty cents per ton delivered at the head of the shaft. In hand jigging about one and a half tons of ore can be treated in a day of nine hours, for which the jigger is paid from $2.25 to $2.50. The treating of the ore at the concentration plants is, of course, more economical. Allowing for all actual expenses of operation, the preparation of a ton of ore, ready for the smelter, costs the small operator between $20 and $25. Royalty, taxes and all other charges add to this amount from $3 to $5 per ton. But some of the larger companies who own the source of production as well as concentrating plants and smelters can bring the ore to the retorts at a total cost of $15 per ton.

Current Topics

In the early days of the so-called safety boilers,—those of the water-tube and sectional types,—much stress was laid upon the safety element which existed in one of these generators because of the opening, under any accidental severe pressure, of the joints between the different units making up the structure. This, it was claimed, caused every joint, and there were a good many of them, to become, for the moment, a safety valve, so that the excess of pressure was, or was intended to be, relieved, and all these numerous joints were expected to close again promptly and to continue, as before, perfectly tight. Several cases occurred in which these joints did open duly upon this special call, and pressures were relieved, but the possibly unlooked-for contingency developed that many of the joints refused to close again. Thus this important part of the duty of a safety-valve was omitted, with the result that the faced joints became rusted or scaled and the boiler was transformed into one of those hopelessly trying things, a permanently leaky boiler.

The largest rifled guns heretofore constructed are the Italian gun with a calibre of 17.76 inches, the French gun of 16½-inch calibre, and the Armstrong 16¼-inch gun carried on the British battleships *Benbow* and *Sans Pareil*. None of these, however, compares, in point of energy and range, with the 16-inch gun turned out at the Watervliet Arsenal gun factory, at Watervliet, N. Y., for the sea coast defence of the United States. Eighteen of these guns have been recommended by the United States sea coast defence board for the protection of New York Harbour, ten for San Francisco, eight for Boston, and four for Hampton Roads. According to a report on this gun, made by Colonel J. P. Farley, Ordnance Department, U. S. A., its range and energy will, of course, vary with the quality and amount of powder used, and the question of the actual performance of the gun can, therefore, be determined only by actual trial tests. With smokeless powder as at present proposed, the gun requires a powder charge of 576 pounds, but if the old black powder is used, 1176 pounds will be required. With a maximum powder pressure of between 37,000 and 38,000 pounds to the square inch, it is estimated that the gun will throw a projectile weighing 2370 pounds with a muzzle velocity of 2300 feet per second, developing a muzzle energy of 88,000 foot-tons; but it is not improbable that

by using a slower-burning powder, giving a less maximum pressure (these being the qualities constantly sought for in the manufacture of smokeless powder), the gun would develop even greater velocity and energy than this, with a relatively small increase in the chamber pressure. Even on the basis given above, however, this gun shows an enormous superiority to any of the large guns above mentioned. The Italian gun, for instance, throws a projectile weighing 2000 pounds with a muzzle velocity of 1700 feet per second, and an energy of only 40,000 foot-tons, an energy considerably less than one-half that of the new United States army gun; the French gun projectile, weighing 1700 pounds, with a muzzle velocity of 1700 feet per second, developed a maximum energy of 36,000 foot-tons; while the British gun projectile, weighing 1800 pounds, with a muzzle velocity of 2100 feet per second, showed a total energy of 51,000 foot-tons. The maximum energy of the Italian gun was thus 45 per cent., of the French gun 41 per cent., and of the British gun 65 per cent. that of the American gun. The projectile of the latter will be 5 feet 4 inches in length, and the penetration in steel at the muzzle corresponding to the energy given above is 42.3 inches.

UNDOUBTEDLY the most spectacular feature in connection with this gun is its enormous range, which is estimated at about 21 miles, or, to be exact, 20.978 miles. This theoretical range has been calculated by Major James M. Ingalls, Fifth United States Artillery, for many years instructor at the Artillery School for Officers at Fort Monroe, Virginia. A firing table for the gun prepared by Major Ingalls shows that the above range is obtainable with a muzzle velocity of 2300 feet per second, with the necessary angle of elevation of the piece. The trajectory of the projectile shows that in ranging to 20.978 miles the shell would reach the maximum elevation of 30,516 feet. This is enormously greater than the maximum range hitherto obtained by any other gun, which, at present, stands to the credit of a Krupp 9.45-inch gun, fired on the Meppen range, in the presence of the Emperor of Germany, on April 28, 1892. The measured range was found to be 22,120 yards, or, roughly speaking, 12½ miles. The greatest height reached by the Krupp shell in its flight was 21,456 feet, and the time occupied between the firing of the gun and the striking of the projectile was 70.2 seconds. It was pointed out that had this gun been placed at Pré St. Didier, in the Alps, elevated to 44°, and fired, its shell would have ranged 8,956.8 feet higher than Mont Blanc, and its fall would have been in the neighbourhood of Chamounix, on the other side of the range. This performance, great as it was, becomes positively insignificant compared with the capabilities of the new United States army gun. With the extreme height of trajectory of 30,516 feet, or over 5¾ miles, the projectile would, in its flight, rise higher than the combined heights of Mont Blanc and Pike's Peak, measuring, respectively, 15,779 feet and 14,083 feet. The total length of the gun is 49 feet 3 inches. The diameter of the rear portion is 60 inches, while the forward part gradually diminishes to 28 inches at the muzzle. The length of main bore is 37 feet 4½ inches. The cylindrical part of the powder chamber is 90.7 inches long, with a diameter of 18.9 inches. The weight of the gun is 126 tons.

YANKEE ingenuity, of which so much has been heard of late, calls to mind an amusing incident in the experience of an engineering acquaintance in California. In order to carry water across a winding ravine, a party of Yankee miners laid a hose of some length, with slight inclination, and at its lower end rising about 20 feet vertically, discharging into another ravine. The discharge end was, of course, lower than the inlet, but from the configuration of the ground an uneducated eye would have judged that the first part of the hose was about

level, and it, therefore, seemed astonishing to see the water all at once rise the 20 feet. A party of Germans noticed this effect with wonder, and laid for their claim a hose nearly level from its inlet, giving it at the lower end a similar vertical ascent of 20 feet. To their chagrin, no water would run through, and they could not get it through their heads how the Yankees could make water run uphill when Germans could not.

THE nineteenth century has been pre-eminently the engineer's century, said Dr. Thurston recently in a lecture at Cornell University. The engineer, the mechanic, the inventor have, from prehistoric ages, been active in the work of the world, and, in premythologic days, the success of the engineer was so appreciated as to give him, in the mythologies of following generations, the rank of demi-god. But there has never been a century since the world began in which his opportunities have been so tremendous or his work so marvellous or the outcome so astounding. The steam-engine, the automatic machinery of all branches of production, the substitution of the system of extensive manufacturing for the older method of making a single machine or product by itself, the introduction of steamboats, railroads, and telegraphs and telephones, widely distributed power, world-wide transportation and their myriad accessories and consequences, have made a new world within the century, and the engineer has been the director and the creator of practically all this phantasmagoric change. Even the great developments observed in agriculture, and those of iron and steel production, are largely due to his provision of the reaping and the mowing machine, the binder and the thresher for the one department, and of the blowing-engine, the steam shovel, hoisting machinery, and the rolling mill and its accessories for the other. The reduction of all industrial production to what is to-day recognised as a sound commercial system, a good business basis, has thus been the work of the engineer. The facts that length of life is measured by its experiences and its accomplishments and that a day at the beginning of the twentieth century counts for more than did a month a century earlier, that life is so much fuller and richer, that so much more can be seen, and done, and felt, and gained in the year, that a youth entering into life to-day has so much more of opportunity, such vastly better chances of success in life, such immensely greater certainty of acquirement, if he so will, of knowledge, comfort, luxury, and often, very often, far oftener than ever before, fame or wealth or happy home,—all these come largely of the progress of the world in the domain of electrical engineering, and where that progress has not been directly active, it has always, in all directions, material, intellectual, even moral and spiritual, had a very important, even though indirect, influence.

IT seems peculiar that in a country like the Philippine Islands, which has been populated so many years, there should be a shortage of iron, and yet, according to a bit of interesting correspondence in *The Iron Age* not long ago, the dearth of that metal there appears remarkable. Iron, we are told, is wanted for the manufacture of tools, farming implements, building trimmings, weapons, and hundreds of other articles. The wheelwrights are looking everywhere for iron with which to repair and construct vehicles. The mining engineers are paying large sums of money for pieces of old iron for use in the various mining enterprises. Owners of sugar-cane crushing machinery, proprietors of machine shops, and shipbuilders are offering all sorts of prices for iron, steel, and other metals. Yet it is almost an impossibility to buy iron in the islands. Native machine workers produce hundreds of different kinds of metal implements and parts of machinery from old vehicle springs and waggon tires. In fact, the main iron supply of the islands seems to have

been obtained from the old tires and springs of vehicles shipped there from Spain for the past generation or two. Spain never made any arrangements for the supply of suitable iron for the islands, although it is a well-known fact that there are deposits of iron in the mines of Mindano, Cebu, Negros, and Panay. However, none of these mines are worked for their ores, and they cannot be counted in the present demand for iron.

THE Spanish authorities failed to furnish the islands with a great many things, but they were good enough to sell to the rich of the country many thousands of poorly-built vehicles The landowners, merchants, and many others of the islands have always purchased freely of the Spanish carriage makers, with the result that the country is well supplied with wheeled vehicles. During the past 100 years many thousands of these vehicles have been cast away and permitted to decay upon the junk piles. Looking upon these wrecks of past days it will be noted that every particle of iron has been removed from them. As soon as a vehicle has finished its days of usefulness it is turned over to the nearest wheelwright, machinist or metal worker, who proceeds to remove every bit of iron, paying for it ten, fifteen, twenty, and often as high as thirty cents gold per pound. If it were not for the iron secured from the castaway vehicles of the country the smiths of the islands would have been in bad circumstances during the past generation.

THE collectors of old scraps of iron in the islands make considerable money. They go from town to town and buy up old vehicles and any devices that may have iron on them. They then remove the metal and sell it to the consumers at good prices. During the past few months two or three very good machinery and general supply stores have been opened in Manila, and these stores are carrying lines of iron which they sell at reasonable prices; but it will be a long time before iron workers through the islands get into the custom of buying new iron, so long have they been obliged to utilise and work over the old scraps. In Iloilo one of the general supply stores which carries hardware has put in a supply of iron, but it is of not much avail to the general iron worker for the reason that as soon as the owners of the store receive a new stock of iron someone else always buys it up immediately at greatly advanced prices and gives no chance for the ordinary buyer to get a share, unless, perchance, he is on the wharf when the goods are landed. The same conditions prevail on Negros, where the writer happened to be at one time when a ship arrived with some supplies of iron. The purchaser operated a local store and invested about $500 gold in iron. He managed to get some of the iron as far as his store where his customers could look at it, but the greater portion was bought up at high prices by men on the wharf. The storekeeper told the writer that he wanted to retain some of the iron so as to carry a stock to accommodate his regular customers, but he could not resist the tempting cash offers of the men who approached him on the wharf. He cleared about $1000 gold in cash on what he sold at the wharf, and had some of the iron left with which to furnish customers at retail. Old carriage springs and wheel tires, as already mentioned, form the principal metal from which the needed tools are made. Often this metal is eaten through by corrosion. Scale can be scraped off in several thicknesses. Quite a goodly-sized piece of iron is worked down to small proportions when the defective part is removed. Yet these pieces of refuse metal are highly treasured. They are kept locked up constantly. The owner values them at high prices. If the scarcity is very great, the iron is practically priceless for the time being.

THERE are none who suffer so much from this lack of iron as the machinists

of the country. Some shops have been idle for weeks at a time, with many orders ahead, owing to no iron being available. Orders are constantly coming in from sugar-cane crushers, operators of oil factories, miners, and others for parts of machinery which have given out and need renewal, and often these orders cannot be filled for protracted periods. In one instance repairs had to wait until a certain ship arrived with the needed metal, the delay being about four months. Some collectors of iron have made good hauls from burnt and abandoned sugar mills. The Spaniards used a form of iron disk for clamping the walls of the churches and convents on the islands, and where these buildings have tumbled to ruins the local machinists have secured the disks and shaped them into gear wheels. These, however, are only a few examples of the various schemes resorted to by the native workers to fill orders.

APROPOS of the repair account for compound locomotives, once a most vigorously discussed subject, and still of very practical interest to railway companies, Mr. S. M. Vauclain, of the Baldwin Locomotive Works, of Philadelphia, said recently, before the New England Railway Club, that on one particular railway where all the engines are now four-cylinder compounds an actual economy in repairs was found as compared with the records of single-expansion engines. This was not arrived at by comparing two locomotives, but by the repair accounts from year to year. The first test of repairs, however, was between one of the very first compound locomotives on the line and nine single-expansion engines, built at the same time, exactly similar in all other respects. By the time that the nine simple engines had passed through the repair shops the superintendent of motive power ordered the compound in to be repaired, and to do such repairs to her as would put her in first-class condition, and turn her out on the road again for service. After that was done the entire repair account of these locomotives from the time they came on the road until they had passed through the shop was tabulated, and to the astonishment of the superintendent of motive power the one that cost least was the compound engine. From one point of view a compound locomotive might be expected to cost a little more for repairs than a single-expansion locomotive, this view being based upon the presumption that compound locomotives carry higher pressure of steam than the ordinary simple engines, and have two more cylinders than the ordinary single-expansion engine, which mean more joints, more packing, and more piston-rods. But even if there were no offsets to this in reduced repairs in other directions, in the matter of boiler and fire-box repairs, for example, those of the valve gear, and others, the statement seems safe to make that the repairs to a compound locomotive are not sufficiently greater than those of a single-expansion engine to warrant any railway to continue using single-expansion locomotives. The economies obtained in other directions are, indeed, so large that no railway can economise to a greater extent in its motive power department than by substituting some class of the compound type locomotive for its motive power.

BISHOP POTTER, recounting, in the *Century*, his impressions of Japan, declares that the sight which lives most vividly in his memory was the loading of a steamship at Nagasaki with coal. He says:—"The huge vessel, the *Empress of Japan*, was one morning, soon after its arrival at Nagasaki, suddenly festooned,—I can use no other word,—from stem to stern on each side with a series of hanging platforms, the broadest nearest the base, and diminishing as they rose, strung together by ropes, and ascending from the sampans, or huge boats in which the coal had been brought alongside the steamer, until the highest and narrowest platform was just below the particular porthole through which it was received into the ship. There

were, in each case, all along the sides of the ship, some four or five of these platforms, one above another, on each of which stood a young girl. On board the sampans men were busy filling a long line of baskets holding, I should think, each about two buckets of coal, and these were passed up from the sampans in a continuous and unbroken line until they reached their destination, each young girl, as she stood on her particular platform, passing, or, rather, almost throwing, these huge basketfuls of coal to the girl above her, and she, again, to her mate above her, and so on to the end. The rapidity, skill, and, above all, the rhythmic precision, with which, for hours, this really tremendous task was performed, was an achievement which might well fill an American athlete with envy and dismay. I took out my watch to time these girls, and again and again I counted sixty-nine baskets,—they never fell below sixty,—passed on board in this way in a single minute. The young girl stooped to her companion below her, seized from her uplifted hands a huge basket of coal, and then, shooting her lithe arms upward, tossed it laughingly to the girl above her in the ever-ascending chain. And all the while there was heard, as one passed along from one to another of these chains of living elevators, a clear, rhythmical sound, which I supposed at first to have been produced by some bystander striking the metal string of something like a mandoline, but which I discovered, after a little, was a series of notes produced by the lips of these young coal-heavers themselves,—distinct, precise, melodious, and stimulating. And at this task these girls continued, uninterruptedly and blithely, from ten o'clock in the morning until four o'clock in the afternoon, putting on board in that time, I was told, more than one thousand tons of coal."

It has often been questioned whether it is advisable to burn castings which are broken or otherwise defective, even after a great deal of expense has been put upon them, and the readiest conclusion generally is that it is impossible to mend a casting by that process. Mr. Edward B. Gilmore, however, in a paper recently read before the American Foundrymen's Association, brought forward several points worth bearing in mind in trying to do such work, and told of the successful burning of some castings which many founders probably would have considered hopeless. In one instance, in making a marine engine cylinder, a piece was broken from a sharp point of the exhaust core which the coremakers had not fastened securely, and this caused a hole to be left clear through to the outside of the casting. In the procedure followed, the casting was put upon a car with the defective side uppermost. Loam moulds were made to cover this, and also to fit the inside of the casting at the same place, the moulds being given a coat of blacking, being thoroughly dried and secured tightly to the casting. A runner was then made to take off the metal poured upon the casting, the overflow being caught in another ladle placed for the purpose. After all the arrangements had been completed, the whole thing was put into an oven and thoroughly heated. Upon this heating the success of the operation largely depends. Six hundred degrees Fahrenheit is about the right temperature, according to Mr. Gilmore. After an oven is thoroughly heated with the usual coke fire, he says, about an hour and a half before the metal is ready for burning feed the fire in the oven with soft wood, and continue doing so until ready. This will raise the temperature to the desired point. In order to assure yourself that the oven is hot enough, you can put a piece of lead upon the car; if it melts you may be certain that you have the temperature high enough,—lead melting at 612 degrees F. When everything was ready in the case under discussion the car was pulled out of the oven. The metal, good and hot, was poured into the mould prepared upon the casting, enough being used to melt the casting about one inch on either side of the defective part. Dry charcoal

blacking was used to cover the cast, and then the whole thing was run back into the oven and let cool gradually. Mr. Gilmore has burned a number of large castings on this principle, and has been successful in every instance. The iron used for this purpose should be of the very softest nature, so as to keep down the shrinkage, and make it easy for machining and chipping.

THERE are many castings which can be easily burned without being brought up to this excessive heat, such as when one has to mend on some extreme point, where undue expansion and contraction will not matter. Some founders, in burning castings, make a practice of bringing the metal forward in small ladles, with the idea of thus having it very hot. This, Mr. Gilmore thinks, is a mistake. The metal necessary should all be put into one ladle, and by thus having a large quantity the temperature will be held for a longer time, and a good, steady stream can be maintained on the part to be mended. As to the question, often asked, whether a casting is as strong after being burned as it was previous to being broken, Mr. Gilmore states that in a great many instances it is stronger, as often there has been a contraction strain on the casting which has been relieved by the breaking. Properly mended, therefore, such a casting should be quite as strong as it was originally.

SIR JOHN AIRD, BART., M. P.

Contractor for the Nile Reservoirs

A BIOGRAPHICAL SKETCH

VAST as are the engineering works for which the land of the Pharaohs was noted more than five thousand years ago,—at a time when King Mena built his "barrage" and turned the Nile from its course in order that he might erect the city of Memphis where the historic river had flowed onwards for ages,—none is greater than the latest effort to harness and bind the Nile, for which Sir John Aird and his firm are responsible, and of which a partial account is given in the leading article in this issue.

As his name implies, Sir John Aird is of Scotch descent, his father being Mr. John Aird, of Ross-shire. The subject of this sketch, however, was born in London on December 3, 1833, and was educated at private schools, from which he went direct to assist his father in business, the latter being also a contractor. Mr. Aird, the father, was responsible for the building of the Great Exhibition in Hyde Park in 1851, and Sir John, who was then only a lad of 18, had charge of this important work, as he had of the construction of the building later on at Sydenham, now known the world over as the Crystal Palace. In those early days young Aird gave ample evidence of that great business capacity and skill which have since carried him to fame in his profession. As Sir John commenced to work when he was young, so he married at a comparatively youthful age. Being thus settled in life at the age of twenty-two, young Aird was able to devote himself almost solely to the prosecution of the great works his father had in hand at a time when many men have scarcely thought of any serious calling.

The life of Sir John Aird has ever been an active and a busy one,—a life made up of carrying into effect great schemes and huge contracts, the very

dimensions of which are sufficient to stagger the average man. At the present time he is at the head of two eminent firms in the world of contractors,—John Aird & Co., and John Aird & Sons, of Great George street, Westminster. Sir John, however, has, in days gone by, been associated with gentlemen whose names are household words in connection with railway and dock building and other great enterprises. As assistant to his father, Sir John carried out the construction of the first waterworks at Amsterdam, Copenhagen, and Berlin, and also the gasworks in Copenhagen, Moscow, and various cities in Brazil, France, and Italy. He was, later, associated with the firm of Brassey, Wythes & Aird in the construction of the great waterworks at Calcutta, then with Sir John Kalk in the building of the Milwall Docks, and with Messrs. Peto & Betts in works in Sardinia. The firm then became associated with Messrs. Lucas Brothers, and carried out many large works in Great Britain.

But the colossal task of damming the Nile is undoubtedly the greatest and most remarkable of the many great tasks Sir John Aird has ever taken in hand, and it very fittingly crowns a long and distinguished career in the engineering world. And if the constructive operations are themselves upon a colossal scale the benefits they will confer upon Egypt are no less important and far-reaching. It has for years been one of the ambitions of Lord Cromer and his associates to dam or bind the Nile with a view to husbanding its superfluous waters when in flood; but for years also France has been opposed to the expenditure of any part of Egyptian revenue on the project, and as she has the whip hand at the Caisse de la Dette, she has up to recently been successful in her obstruction.

But in February, 1898, Sir John came to the rescue, and has now proved himself to be the salvation of Egypt. Sir John in that year offered to construct the necessary dams at Assouan and Assiout in return for thirty half-yearly installments of £78,613, the first payment to be made at the completion of the work in 1903. Sir John Aird's firm contracted to complete the work in five years, and already three years of that period have elapsed. The prospects, however, are so bright that there seems little or no doubt of the completion of the dams in the time specified. The cost of the work is estimated at £5,000,000. No less than 20,000 men are now engaged in the operations. Ninety per cent. of the labour is native, the rest being made up of Italians,—who predominate amongst the whites,—English, Scotch, and Irishmen.

Before he undertook to dam the Nile on such munificent terms, Sir John Aird was well known in public life, but that great work has undoubtedly brought him more prominently before the world. Eventually, as the outcome of numerous requests, he consented to enter Parliamentary life, and since 1877 he has sat continuously for North Paddington, large majorities always ensuring his return. In 1900 Sir John was elected first Mayor of the newly-formed borough, and this honour was followed shortly afterwards by the late Queen conferring the dignity of a baronetcy upon him. This signal mark of royal favour was amongst the most popular, as it was amongst the most deserved, of New Year's honours. Sir John Aird has proved an excellent Mayor, and attends to his municipal duties with that punctuality and brings to bear upon his work all that ability that might have been expected from so distinguished a business man.

PHOTO BY ROCKWOOD, NEW YORK

Chas. R. Flint.

THE "FATHER OF TRUSTS"

SEE PAGE 438

CASSIER'S MAGAZINE

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THE COMSTOCK OF TO-DAY

By T. A. Rickard

A RECENT visit to Virginia City, Nevada, U.S.A., has prompted the writing of these lines in the hope that they may be of interest to those who have never been to a mining district which at one time threatened, by the magnitude of its silver production, to disturb the financial systems of the civilised world. A few days previous to this, his first visit, to the mines of the Comstock lode, the writer had been southward of Washoe county in that sterile tract of Nevada which follows the eastern slope of the Sierra Nevada and extends through Candelaria toward the never-never lands of Death Valley. It was evening as the train slowly climbed along the contours of the Virginia range until Mount Davidson, with Virginia City and Gold Hill at its feet, came into view. All who are engaged in mining have read of the Comstock in student days; its yield of gold and silver has fired the imagination of many, and the operations carried out on the big lode have been of such a magnitude as to give them the foremost place among the achievements of mining engineering. Nor has the human interest been wanting. Mark Twain has peopled the streets of Virginia City with characters that will live when the underground avenues of the mines are forever stilled. The men who there won wealth at the point of the pick have taken their place among the Napoleons of finance.

The day was closing, a glow from the west lingered upon the slope of Mount Davidson, the scene, twenty years ago, of extraordinary human activities, and, in a far remoter past, the place of geological movements which resulted in the accumulation of a treasure beyond a pirate's dreams. "Cold upon the dead volcano sleeps the gleam of dying day." There is the feeling of a great energy forever stilled, there is the suggestion of quiet after titanic labour. What Bunninyong is to Ballarat, Pike's Peak to Cripple Creek, Mt. Burgess to Coolgardie, that Mount Davidson is to the story of the Comstock. Although strictly not a volcano, it is built of rocks of igneous origin which played an important part in the geological record, because the steep slope of the mountain has been proved to be the continuation of the footwall of the big lode. Inci-

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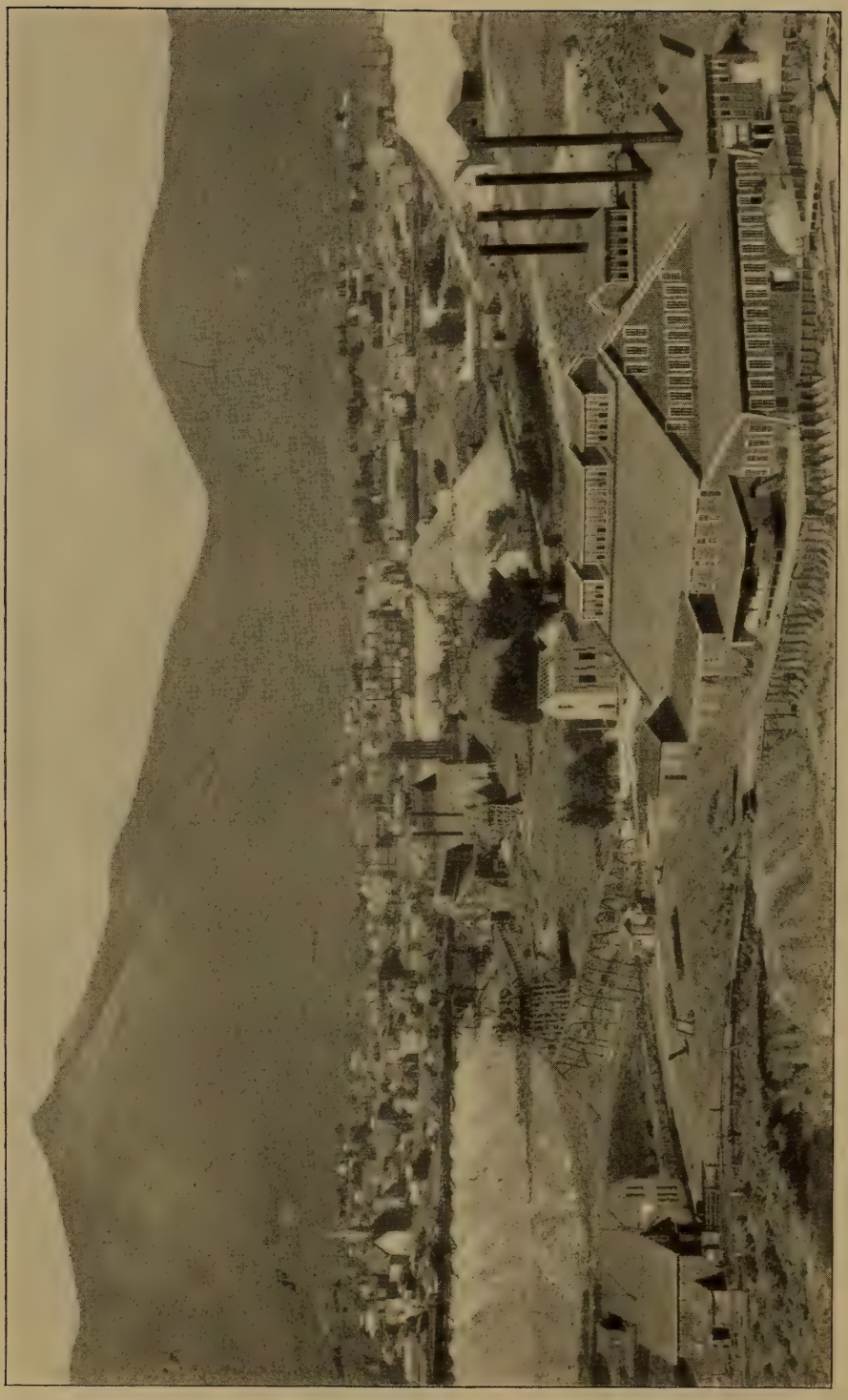


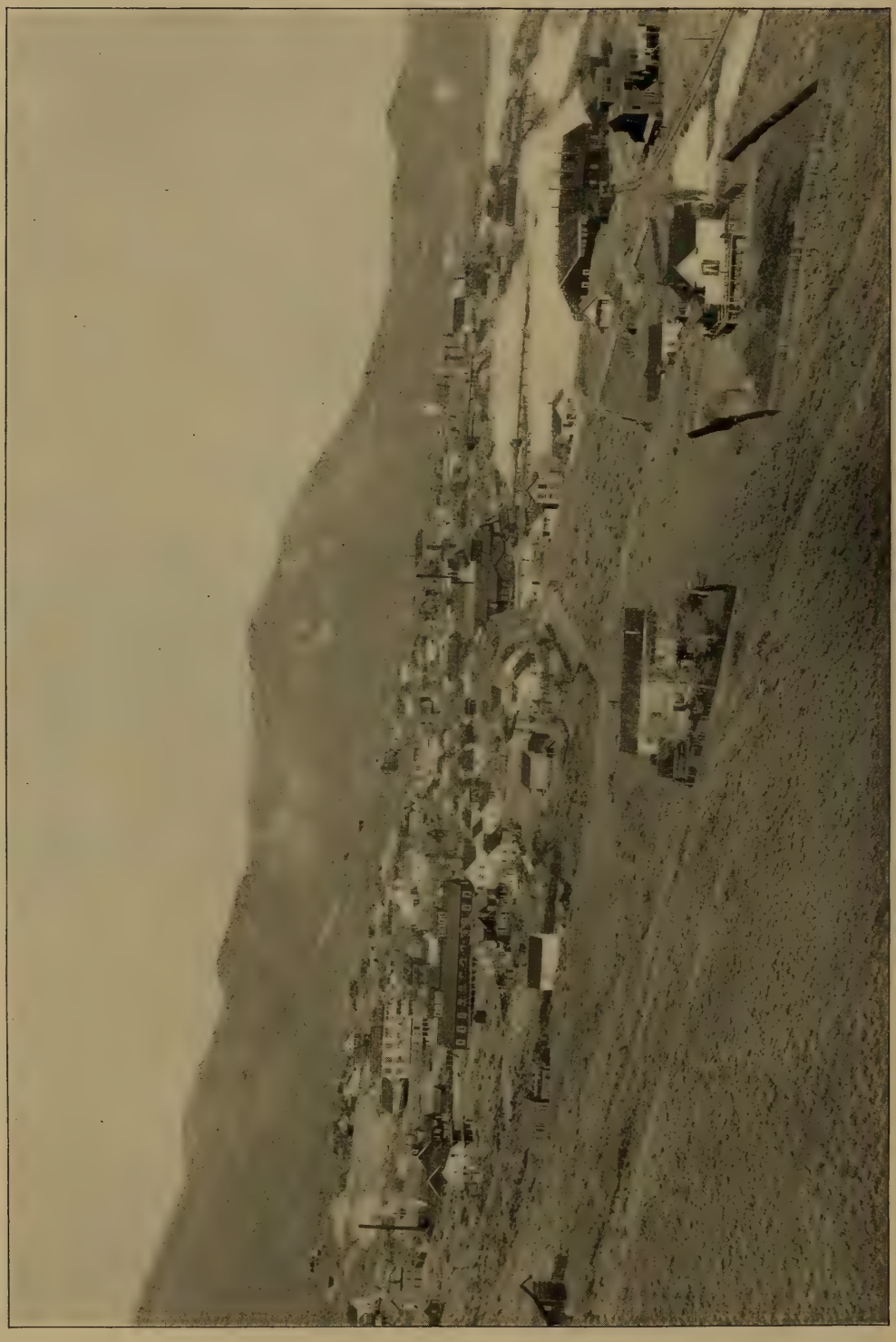
A VIEW OF VIRGINIA CITY, SHOWING THE CONSOLIDATED CALIFORNIA AND VIRGINIA MILL IN THE FOREGROUND

dentally, the rock of which it was formed became the subject of much debate among petrographers. It was first labelled syenite by Von Richthofen, but Zirkel determined that it was granular diorite, while Hague and Iddings finally demonstrated that the diorite was a structural variety of diabase.

The shaft houses of the mines are situated among the streets of Virginia City and Gold Hill, a twin township, like Bendigo and Eaglehawk, or Central City and Nevadaville. They occur in three series, each readily recognisable. lode at increasing depths. The illustration on the opposite page shows Mount Davidson in the background and the Consolidated California and Virginia mill in the foreground. To the right is a part of the dump of the Ophir Mine, and to the left is the rock which came out of the *C* and *C* shaft. Like most old camps, Virginia City has sufficient trees to soften the ugliness of the dwellings. Many of the old buildings have been torn down, owing to their dilapidation; others have collapsed on account of the

THE CONSOLIDATED CALIFORNIA AND VIRGINIA MINE HOISTING WORKS, BUSINESS AND ASSAY OFFICE BUILDINGS

The first line of shafts is close to the western outskirts of the town, up the slope of Mount Davidson and near the croppings of the lode; the next series, east of the first line, and deeper, traverses the centre of the settlement; while a third, and last, series of shafts, which was sunk in the hanging-wall country, is further to the east, and is marked by imposing buildings and equipments. The Comstock is a comparatively flat vein, the foot-wall dipping at an angle of about 40 degrees, so that the successive extension of exploratory work brought about the gradual shifting of the position of the main shafts, which were vertical and designed to cut the sinking of the ground due to the enormous excavations underneath, but the town can still boast some good-looking structures. The old pioneers point out the places of memorable scenes and the former homes of multi-millionaires, now well known in Paris and London. Among others, the writer was shown the little white house where James Fair lived, and where was born Miss Virginia Fair, who, a few years ago, wedded W. K. Vanderbilt, Jr. The grandson of old "Commodore" Vanderbilt, who captained a steam-tug on the New Jersey coast, and the daughter of James Fair, who worked in the mines of Nevada, were thus destined by their



ANOTHER VIEW OF VIRGINIA CITY NEVADA

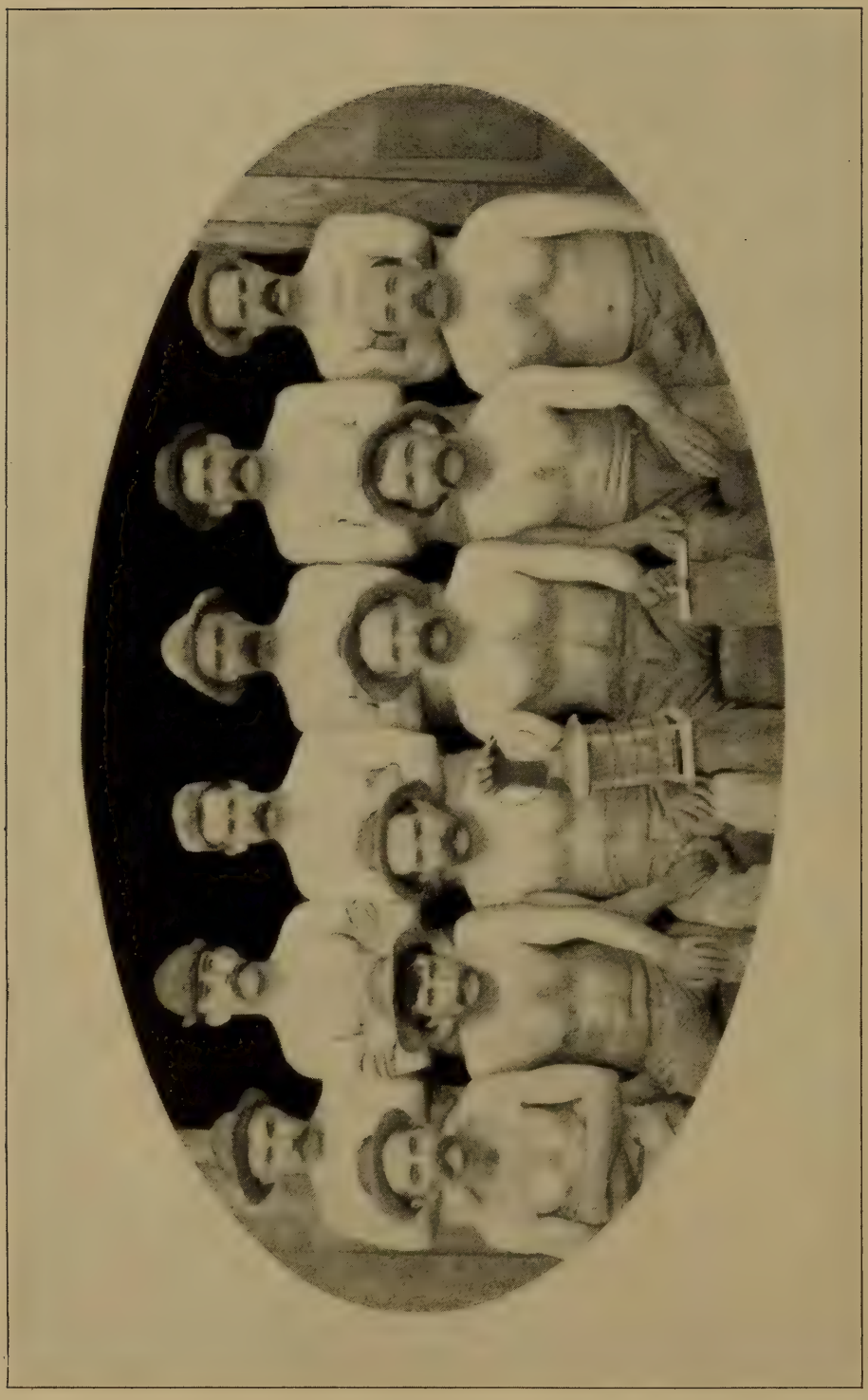
marriage to represent the union of two colossal fortunes.

The story of the Comstock runs in big figures. The output has been variously stated. Statistics give it inadequately, because the losses made in milling and the sums stolen represent enormous additional amounts which are unconsidered in departmental records. It is probable that the gross yield of gold and silver, from the beginning to this day, will approximate a value of four hundred and fifty million dollars. The Consolidated California and Virginia Mining Company, generally known as the Con. Virginia, had produced $131,759,339 up to the end of 1899, and had paid out in dividends the sum of $78,148,800. The ore body which yielded the bulk of this immense profit extended from the 1200 to the 1700-foot levels, the uppermost portion reaching up to the 1100-foot level, and the bottom of it dwindling below the 1800-foot level. The "great bonanza" was not easily discovered. In the earlier years several shafts were sunk on the claims subsequently consolidated to form the Con. Virginia, but no ore bodies of value were encountered. It is said that James Fair, then acting as superintendent of the neighbouring Gould & Curry mine, first found ore while running a northern drift into ground which he knew to be outside his boundary lines. When he made the discovery he joined with Mackay and Flood in securing the Virginia and California claims. So the story goes. The spirit of it represents very fairly the ethics of mining as understood on the Comstock.

When the bonanza began to be productive, in 1874, it made the Con. Virginia a marvel among mines. The average yield for three years was $3,000,000 per month. The dividends were at the rate of $1,080,000 per month. In 1876 John W. Mackay, who was then superintendent, took out six millions in one month in order to make an exhibit of bullion for the Centennial Exhibition at Philadelphia. You can visit the assay office at Virginia City and Mr. Fielding, who still has charge of it, will tell you that there was melted in that office $125,000 worth of bullion per day for three years, and that one night there was taken out of the strong-room, for shipment to San Francisco, bullion valued at $5,000,000.

These figures make the ordinary digging for gold seem tame enough. It is not surprising that under such conditions human nature should have asserted itself, and that the prolific production of the mines should have led to a reckless extravagance of ideas and of expenditure. The money paid in commissions to superintendents, the steals perpetrated by the reduction works, the tricks played with the stock market, were all mean and despicable, as such performances in their nature must be; but they were perpetrated on the Comstock with such a magnificence of proportion and with such grand-ducal impudence that their true character was obscured by a glamour incomprehensible to those who have kept out of the atmosphere of insensate speculation. The price of the shares of the Sierra Nevada mine, for example, rose in eight months from 50 cents to 275 dollars per share. This was in 1882. One thousand dollars became more than half a million in less than one year. This is unearned increment with a vengeance! No wonder the people of San Francisco tumbled over one another in their eagerness to buy stocks, and the servant girls and the office boys gambled all they possessed in the mines of Virginia City, which, save for the absence of the glitter of splendid salons and the suave voices of inviting croupiers, was a greater Monte Carlo than the one which suns itself on the Mediterranean shore.

Soon after the Con. Virginia began its enormous production the stockholders and manipulators of the principal mining companies demanded that the shafts be sunk deeper in order to penetrate another supposed lower zone of rich ore bodies. Several shafts were sunk, including the Union, the *C* and *C*, and the Combination. The last mentioned is the deepest. It was the joint enterprise of the Chollar, Savage, and Hale-Norcross companies. A ver-



A GROUP OF COMSTOCK MINERS

tical depth of 3260 feet was attained. It is estimated that seven million dollars were expended on this shaft and in the unsuccessful explorations made from it. The Union shaft was sunk with great rapidity, and eventually, through winzes from the bottom levels, reached the greatest depth attained, namely, 3350 feet. This was about 3500 feet below the outcrop of the lode.

The datum line for all such measurements was the level of the Gould & Curry croppings on the side of Mount Davidson. The big lode outcrops in several places along the flank of the mountain, especially on Cedar Hill, where surface mining still continues. However, to the visitor from the newer gold fields it seems remarkable how little of the surface of the surrounding country has been disturbed. It appears as though the idea prevailed that prospecting outside the big lode was useless, nature having lavished all her riches on the one vein.

The outcrop on the Ophir claim was the point of first discovery. In the early part of 1859 several prospectors, who had been working the gold-placer diggings in the cañon below, climbed up the side of Mount Davidson, and, with the aid of the water from a spring, tested some of the surface dirt in a rocker which they had brought with them. The discoverers were Peter O'Riley and Patrick McLaughlin. These men were dispossessed of the honour by Henry Comstock. The last-mentioned realised the magnitude of the discovery better than the simple miners who really made it, and he thus obtained an interest in their claim, besides, by his assumption of leadership, securing the reputation among the other prospectors, and subsequently before the world in general, of being the Jason of those Argonauts. He died miserably, by his own hand, in 1870, and it is a curious commentary on the hunger for gold which has been so great an incentive to the adventurous of all ages, that both of the other men, above mentioned, also died paupers and without honour

There is another story of the discovery which antedates the events just referred to. There was a military post, called Fort Churchill, thirty miles to the east. The Mexican packers who brought supplies from Marysville, in California, used to pass down the valley of the Carson River and stop to do business with the gulch-miners there. Gabriel Maldanado was the leader of these Mexicans, and was the first to recognise the black lumps in the sluice boxes to be silver ore. This parallels the story of the California gulch placer diggings and the silver deposits of Leadville, which occurred sixteen years later in Colorado. It is interesting to remember that silver mining was unknown in the United States previous to the discovery of the Comstock, so that the gold diggers were as unfamiliar with argentiferous ores as the miners in Australia, for example, were unacquainted with tellurides until Kalgoorlie became a name of renown.

In the summer of 1898 there were not more than a dozen men at work in the mines of the Comstock; at the time of the writer's visit, in April, 1899, there were about 150 at work. Nevertheless, the population at the present time is about 3000, largely comprised of those who saved up money during the boom period, and now remain at Virginia City because they dislike making a fresh start elsewhere. Besides these factors, which tend to prevent the depopulation of the district, there is the hope of better days, a dim expectation founded on the bygone vicissitudes of Virginia City, the thought that times of great activity in the mines may come again. Those who manipulate the shares of the principal mines foster this feeling. Recent developments have given it a colouring.

The unwatering of the Comstock is the principal theme of conversation in the streets of Virginia City to-day. An effort is being made to pump the lower levels.* To appreciate the work recently inaugurated a few notes will be needed. The mines of the big lode were subject to flooding even before they became

* This refers to the time of the writer's visit in 1899.

ENTRANCE TO THE SUTRO TUNNEL, SUTRO, NEVADA

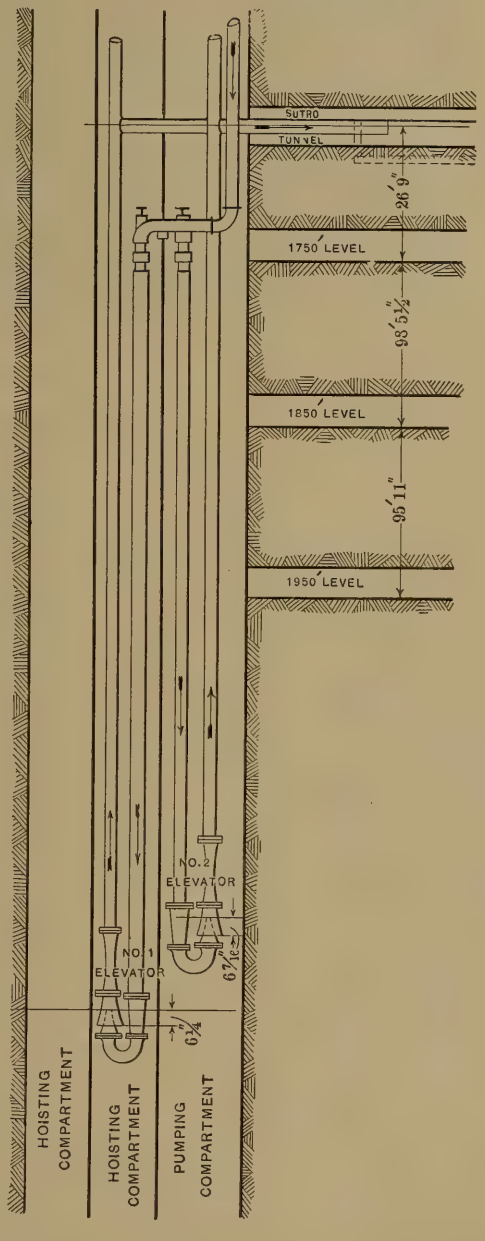
very deep. Several shallow adits were made to drain them while they were yet in the early stages of development. In October, 1869, the Sutro tunnel was commenced. This great adit starts from the valley of the Carson River, and has a length of 20,145 feet, or about four miles. It intercepts the Comstock lode at the Savage shaft, at a point 1895 feet below the outcrop. Eight years, and four and a half million dollars, were consumed in this enterprise. The idea was to drain the mines, but long before the tunnel reached the lode the workings had been extended a thousand feet below the level of it, and the ore bodies had been, for the most part, removed. The amount of water which flowed through the tunnel at one time exceeded 7000 gallons per minute. Nevertheless, like many other tunnel schemes, the enterprise was completed too late, and failed to achieve the purpose for which it was primarily designed. The ore bodies found in the workings below the level of the Sutro tunnel were insignificant compared to the bonanzas discovered in the ground between it and the surface, and thus, though the influences of the stock market kept the deeper levels going, they were finally abandoned in 1882, and allowed to be filled with water. Now comes the cry to drain them and to develop the bodies of low-grade ore which they are said to contain. Whether this is another story like that of Rule's drift, or whether it is a piece of sound business, the writer cannot say, but the method of unwatering the mines deserves more than passing notice.

The water supply for the district comes from Lake Marlett, in the Sierra Nevada Mountains. It is conducted through pipes twenty-five miles in length which cross the deep valley separating the Virginia range from the Sierras. This water is available for hydraulic purposes, because the Sutro tunnel affords a drain nearly 2000 feet below the point of delivery. The idea of employing the hydraulic elevator was suggested by the engineers of the Risdon Iron Works, they, in turn, having obtained the suggestion from the practice of the alluvial mines in Otago, New Zealand. This method has been put into execution, and while visiting Vir-

ginia City the writer had the pleasure of seeing the elevator pumping in the Consolidated California and Virginia mine at the 1750-foot level. The water comes down from the surface under a head of 2050 feet and a pressure of 870 pounds per square inch. The pressure pipe is 12 inches in diameter, and the discharge 14 inches. The nozzle is 1⅛ inch, and the water travels at the speed of 340 feet per second. A supply of 1450 gallons of water per minute serves to pump an additional 2600 gallons to the Sutro tunnel, 35 feet above the 1750 foot level. The nozzle and the lowermost section of the discharge pipe are made of phosphor-bronze. The pipe joints are provided with lead-copper gaskets of ingenious design. The pressure pipe weighs seventy-five tons, and is supported by heavy masonry at the 1750-foot level.

In connection with this use of water power mention must be made of the electric plant, for illuminating purposes, which is worked by a Pelton wheel only 30 inches in diameter, operated by a jet passing through a nozzle 5-32 of an inch in diameter and with water at 1500 feet head, so that each miner's inch, or 1.57 cubic feet per minute, generates 4¾ H. P. The success of the elevator will be an interesting event in pumping history. When starting, the vibration set up was very great and the first elevator pipe was shattered by it, but by the employment of phosphor-bronze a stronger material was secured, and by submerging the intake so that the nozzle is 60 to 75 feet under the surface of the water, it has been found that the vibration is very slight indeed. At the time of the writer's visit the elevator was working 192 feet below the Sutro tunnel level, and a second elevator had been put in place. The two have been worked conjointly, and it has been found that they lifted, to the Sutro tunnel, no less than 8000 gallons per minute,—a tremendous flow of water.

The monographs of the United States Geological Survey have made the lode as famous in the annals of geological science as its bullion production made it remarkable in commercial records. Professor Becker's report was prepared between the years 1879 and 1882. His monograph contains a very remarkable explanation of the probable mode of formation of the lode and the ore bodies which it contained. The theories he offers are, in many respects, curiously



HYDRAULIC ELEVATOR IN THE CONSOLIDATED CALIFORNIA AND VIRGINIA SHAFT

opposed to the views on ore deposition generally accepted to-day, and this wide difference of opinion serves to mark the divergence between the ideas developed during later days, as com-

THE OPHIR MINE AT VIRGINIA CITY

pared to those of authoritative geologists twenty years ago.

Mr. Becker explained the lode as a great fault fissure, and he made certain interesting mathematical calculations to prove that the line of it followed a logarithmic curve. His opinion was that the main fissure of the vein was at one time closed nearly water-tight, that hot waters in vast quantities were forced into the fissures of the east or hanging country, that these waters, having become saturated with soluble substances, again sought the main fissure as the path of least resistance and there deposited the quartz and ore. Thus he combined the views of the two schools, —lateral secretion stood wedded to ascension, Sandberger is allied to Posepny. The keynote of the views he held at that time on the subject of ore deposition is contained in the statement that " the first condition for the formation of a quartz body is an opening to receive it." This is a sentence which has always seemed to the writer to suggest ideas which are opposed to observation underground, and it is one which has helped to give to the so-called " fissure-vein " the conception of a deposit formed in a gaping crevasse or underground cave. Later work has modified these older ideas of open cavities, and has accentuated the observation that a great number of very important ore deposits are undoubtedly formed by the slow replacement o masses of crushed rock along lines of fracturing which have afforded, not fissures, but merely bands of maximum porosity, such as have permitted of the slow penetration of mineral-bearing solutions.

One arrives at Virginia City full of the remembrance of its past, and one leaves it, oppressed with a sense of a glory that has departed. The visitor is taken to see enormous shaft-houses and to examine huge engines of antiquated design, only to feel a great regret that the leviathan machinery should be ponderously silent. It is an interesting study to observe how modern winding engines have been evolved from the clumsy and complicated patterns of twenty years ago. The Comstock was a great school of mechanical design. In the mines of the big lode the American engineer first solved the problems of deep development, but the writer doubts whether it was a good school of mines in any other sense than the mechanical. There was skill in the installation of machinery, and there was ingenuity in the adaptation of European methods of timbering to unusual condi-

tions; but in the application of geology to mining, and in the improvement of underground practice, there was not any such advance as has been made by the mines of Michigan, Colorado, and Montana. On the whole, looking at the record fairly, the writer is inclined to think, notwithstanding the mechanical skill of the constructing engineers of the Comstock, that the lode did more harm than good to mining, because it accentuated the gambling and subordinated the industrial feature.

While examining the machinery erected by W. H. Patton at the Union mine I saw written on the wall, "He that enters here leaves hope behind." It must have been a disgruntled shareholder. They can say such mean things when a mine is not disbursing dividends. The engine house of the Union mine is not a cheerful place. Patton's name is inscribed upon the machinery. He went to Australia under appointment as manager of the great Broken Hill mine, but his mental faculties became impaired, and he came home to California to die. Yet sadder than the memory of a fine career untimely closed is, to the writer's mind, the notice of the Miners' Union, in large printed letters upon a red poster, which is nailed to the wall of the shaft-house. The race-horse who, in his old age, pulls the dust-cart, has a nobler ending than a great mining camp in its decadence ruled by the enemy of honest labour. The ukase of the American czar differs little from that of the edicts of his Russian prototype save in a lesser intelligence. It is the last remembrance which the writer took away from the great Comstock lode, save one! On the Carson River I saw the old mills which are now silenced, and the dredges which once worked the tailings from the mills. The valley of the Carson has seen many vicissitudes. Placer mining for gold made it important before the Comstock; then it became cultivated by the industrious folk who supplied the mines with vegetables; later still the mills became centered along the waterway; and finally the Sutro tunnel gave it a short-lived prosperity. The unlovely quiet of abandonment which now rests on the whole district has also fallen on the Carson valley. The Chinaman alone is superior to his surroundings. Amid a general decay he continues to give life to the green spots which his patient hands have won from the sterile surface.

The heathen Chinee and his kitchen-garden form a picture which is the very antithesis of the volcanic energy which once made the Comstock famous throughout the world. The mines are idle, the sunlight falls on abandoned shaft-houses, and the rain rusts the motionless machinery, but

"The river still is winding, still is winding
Past the gardens where the Mongol tends the cabbage and the leek."

THE GLASGOW EXHIBITION

THE ELECTRIC LIGHT PLANT

By W. D. Wansbrough

FOLLOWING close upon the gigantic exhibit of machinery at Paris comes another opportunity,—probably the last for some years,—of reporting progress in that great industry which has done so much to improve the breed, so to speak, of steam-engines,—the generation of electricity for power and for light.

The needs of the electrician have forced the hand of the engineer, and to-day we have vast engines which but a few years ago would have impressed the observer mainly by their slow and stately revolution, now sharing in the general mania for "intensified production," and tearing round,—the word is inelegant, but expressive,—at twentieth-century speed and pressure.

Though not, of course, comparable in size with the Paris Exposition of 1900, the Glasgow show is of very considerable extent; and a mere catalogue of the engineering exhibits would more than fill the allotted space here. We shall, therefore, as in the previous case, confine ourselves to a description of the engines and boilers actually employed in the electrical service, and it will be convenient to take them in the order of the official catalogue, as follows, viz.:—

ENGINE.	DYNAMO.
Willans & Robinson, Ltd. (1).	Crompton & Co., Ltd.
Willans & Robinson, Ltd. (2).	British Schuckert Electric Co., Ltd.
Robey & Co, Ltd. (A).	Mavor & Coulson, Ltd.
Robey & Co., Ltd. (B).	E. Scott & Mountain, Ltd.
Robey & Co., Ltd. (C).	E. Scott & Mountain, Ltd.
Ruston, Proctor & Co., Ltd.	Ruston, Proctor & Co., Ltd.
E Scott & Mountain, Ltd.	E Scott & Mountain, Ltd.
Alley & Maclellan.	Mavor & Coulson, Ltd.
Browett, Lindley & Co., Ltd.	Edison & Swan.
Bellis & Morcom, Ltd.	D. Bruce Peebles & Co.
Sisson & Co.	Clarke, Chapman & Co., Ltd.
Davey, Paxman & Co., Ltd.	Electric Construction Co, Ltd.

These twelve sets of generating plant figure up about 4200 electrical horse-power. Following the official list, we commence with the exhibit of Messrs. Willans & Robinson, Ltd., of Rugby. This consists of two triple expansion engines, each having a normal output of 1200 H. P., with a maximum of 1500 H. P., one being coupled to a Crompton dynamo and the other to a dynamo constructed by the British Schuckert Electrical Company, Ltd.

The external appearance of the Willans engine is so well known that we have by preference illustrated one of the Glasgow engines with the front half of the crank chamber removed (Fig. 1), thus showing the cranks, eccentrics, connecting-rod ends, and one of the guide pistons. The front casting, as just removed from the engine, is visible in the background.

It will be seen that in each complete engine there are three cranks, set 120° apart, each with a complete triple-tandem engine of its own, there being thus nine cylinders to each engine. With this arrangement there is an entire absence of vibration either local or general. Those mysterious earth-tremors which in city stations have proved such a fruitful source of litigation and worry are totally eliminated in cases where three-crank engines, hav-

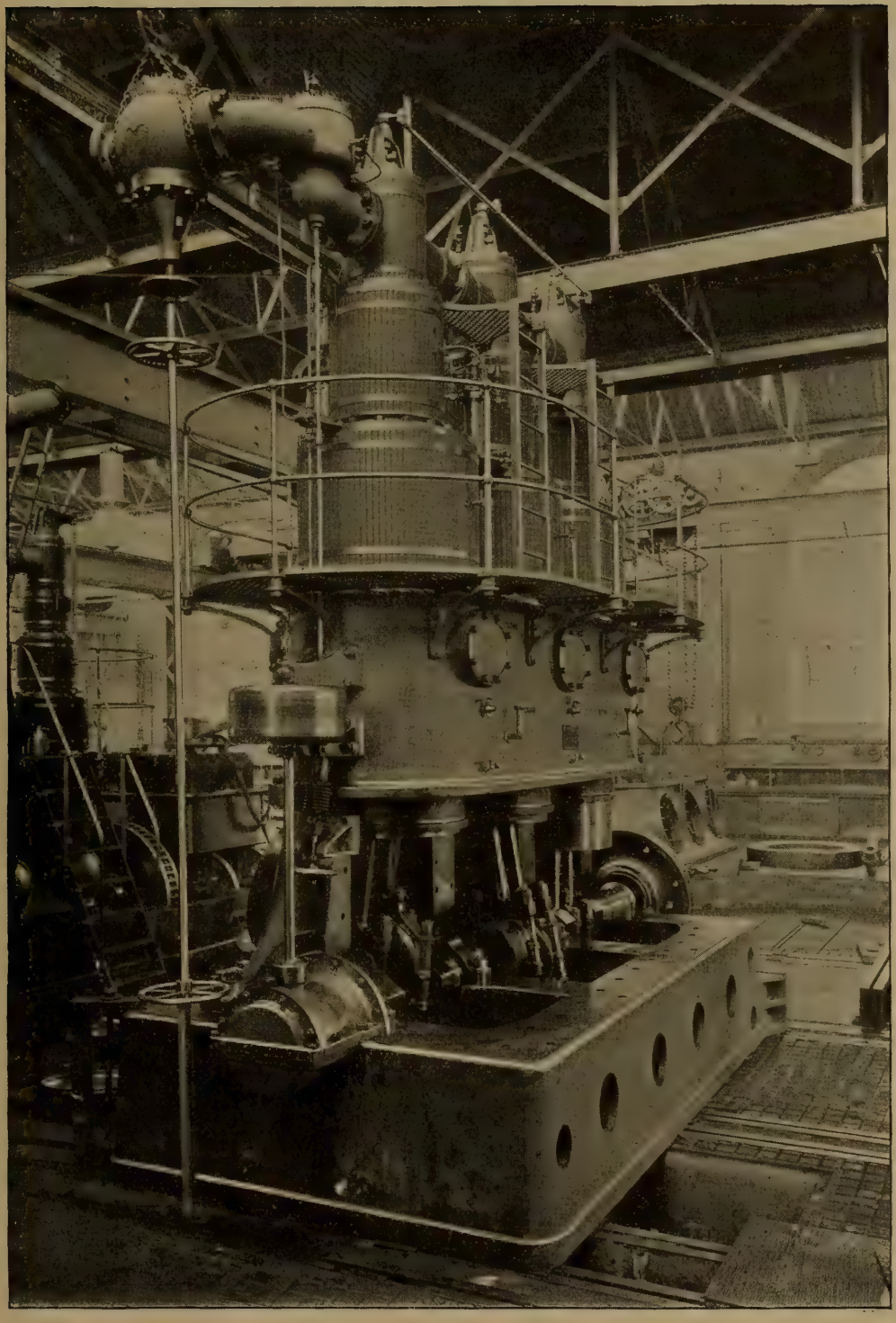


FIG. 1.—THE WILLANS ENGINE. BUILT BY MESSRS. WILLANS & ROBINSON, LTD., RUGBY, ENGLAND

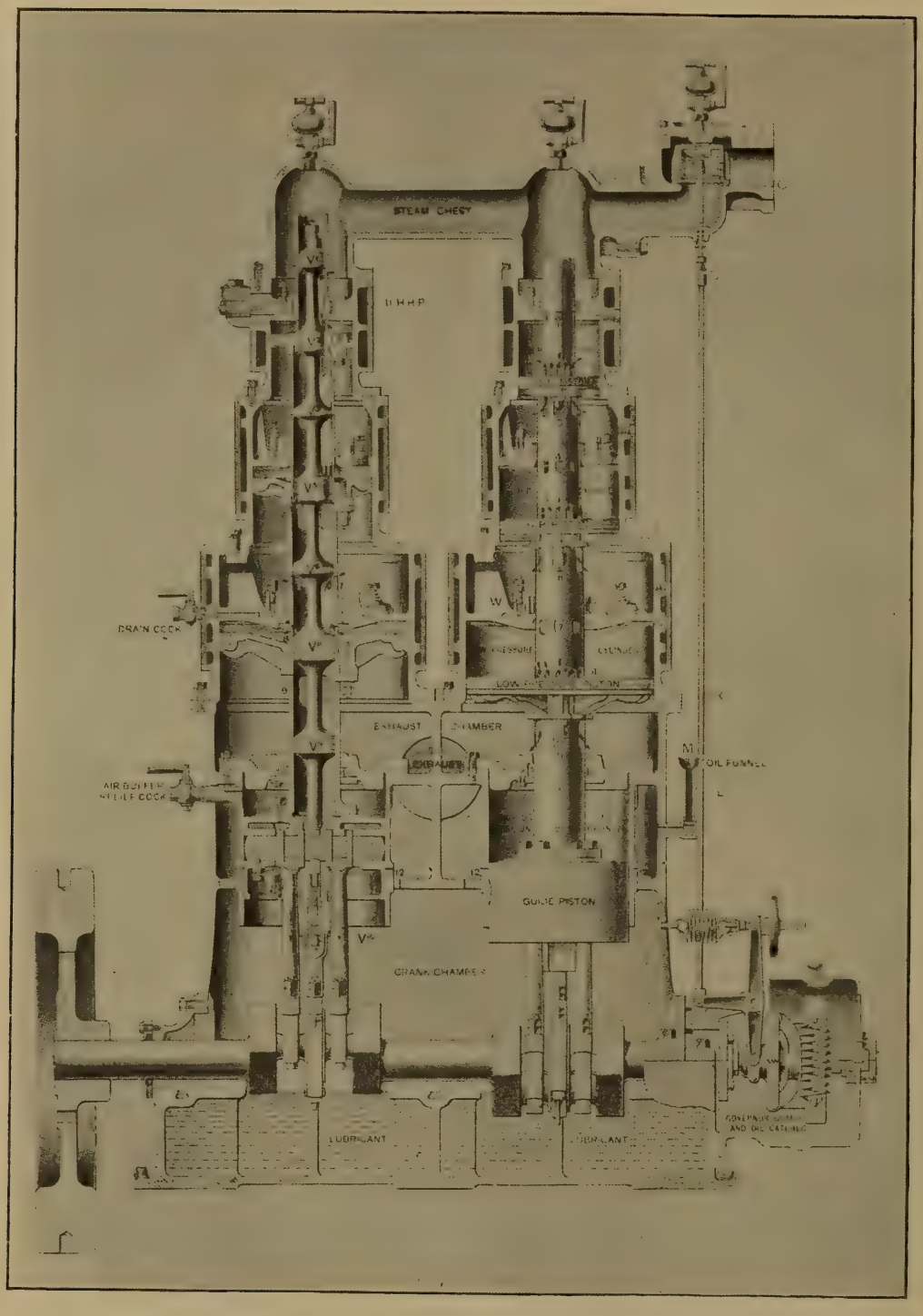


FIG. 2.—VERTICAL SECTION OF A TWO-CRANK TRIPLE-EXPANSION WILLANS ENGINE

ing equal reciprocating weights upon each crank, are employed. Moreover, the convenience in handling, due to the splitting-up into three distinct sections of the cylinders and moving parts in engines of large power, is much appreciated by those concerned in their erection and maintenance.

In the engine before us the cylinders are 15, 23.6 and 37.5 inches in diameter by 17 inches stroke, making 230 single-acting strokes per minute.

A vertical section of a two-crank, triple-expansion engine is given in Fig. 2, by reference to which the leading features of the Willans engine may be easily grasped. First it should be noticed that the weight and pressure upon each bearing and crank-pin are always downwards,—there is no re-

versal of stresses. Hence, the upper halves of the main bearings and the lower halves of the connecting-rod or crank-pin brasses are never intended to come into contact with the moving journals.

To carry this principle out thoroughly it is necessary to provide against the upward "fling," or, in other words, the tendency of the reciprocating parts to continue in motion upwards until arrested by the crank-pin, to the accompaniment of a very unpleasant knocking sound. Compression in the steam cylinders is usually relied upon for effecting this, but Messrs. Willans & Robinson provide an air-compression cylinder, —the lowest in the series, also forming the trunk guide,—by which a permanent air-cushioning effect is produced independently of the steam cylinders.

Looking at the vertical section (Fig. 2), the right hand engine shows the hollow piston-rod and ports; the left-hand engine the line of piston valves. It will be understood that the eccentric sheave is formed upon the crank-pin itself, and thus the motion of the piston valves relatively to the ports in the tubular piston-rod is accomplished.

The steam, after passing the governor valve, enters the hollow piston-rod on the ports marked *1*, and enters the top cylinder by the ports *2* just above the piston. It is important to remember that this ring of ports is the only inlet to and outlet from the cylinder, and that it moves up and down with the piston. In the left-hand engine the pistons and valves are represented in the admission position. The cut off is effected by the ports *1* entering the gland at the prescribed point in the downward stroke, and so preventing any further ingress of steam for that revolution. The cut-off is extremely rapid, owing to the speed at which the piston rod is moving through the stationary gland. Now we come to the "transfer" or Cornish cycle, which is a feature of the Willans system.

After the steam has worked expansively in the top cylinder the valve passes above the ports *2* and opens communication from the working end of the cylinder to the space below the piston. During the up-stroke the steam is simply transferred from one side of the piston to the other; the whole cylinder, including the working end, at that time forms part of the receiver. At the beginning of the next down-stroke this receiver steam is passed into the intermediate (or, as called in the drawing, the *H. P.* cylinder). It enters the hollow piston-rod from the receiver by the ring of ports *4* and reaches the cylinder by the ports *5*. Cut-off in this case is given by the ports *4* passing into the gland in the *H. P.* cylinder cover. The course followed by the steam is exactly the same as described for the top cylinder, and at the end of the second revolution the steam fills the second receiver. Thence, in the third revolution, it passes into the *L. P.* cylinders, and in the upward part of that revolution passes to the condenser or to the atmosphere.

The noticeably concave shape of the upper surfaces of the pistons is designed to aid the drainage of the cylinders. The water is rushed out with the exhausting steam continuously during the upward stroke. Where variable expansion is required, which may be either automatic through the action of the governor, or effected, as desired, by hand, the ports through the hollow piston-rod, instead of being square-topped and disappearing through a gland, are made inclined or spiral in form, and are surrounded by a sleeve capable of rotation and formed with correspondingly inclined or spiral ports. The cut-off is then effected by turning this sleeve to the required position to effect the cut-off.

The method of lubrication, by the splash of the cranks in the mixture of oil and water in the crank chamber, will be noted. Every moving part of the engine, except the cylinders and piston valves, is reached by the splash, so that the lubrication is perfectly automatic.

One of the engines is coupled to a 700-kilowatt Crompton dynamo having twelve poles, and being over-compound-wound for traction work, the voltage being 500 at no load and 520 when gen-

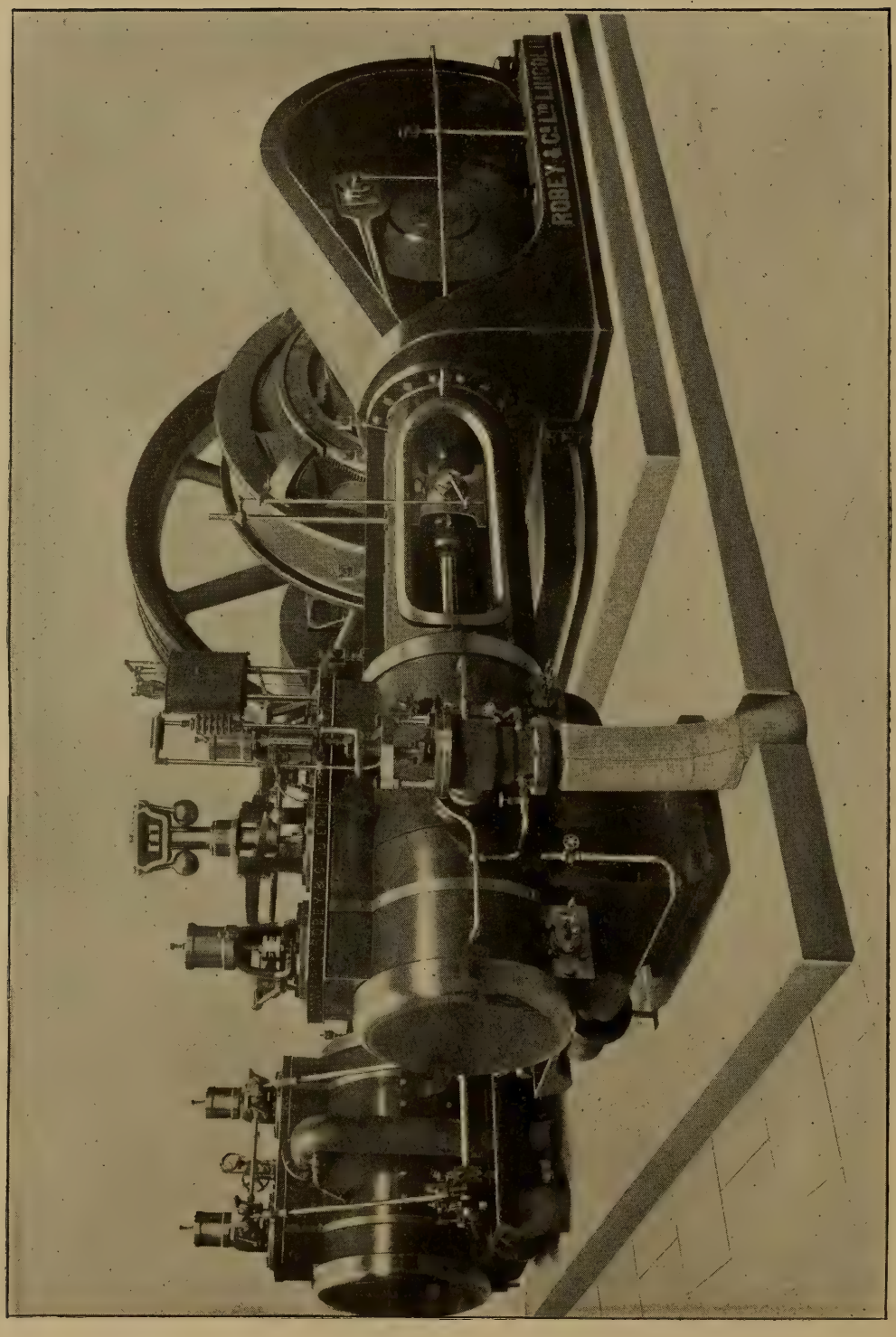


FIG. 3.—A PAIR OF HORIZONTAL ENGINES BUILT BY MESSRS. ROBEY & CO., LTD., LINCOLN

erating 1400 ampères,—the full load for which the machine is designed. The magnet frame is of cast iron, and is in four segments. The poles are of wrought iron, and the series winding is carried round the shunt, with a clearance of about an inch for ventilation purposes. The armature has a toothed core, and is drum-wound. Its diameter is 7 feet 6 inches, and its weight is eighteen tons. The copper strip conductors are 1500 in number and are bent to shape in formers before being placed in their slots. Of these slots there are 250, and the commutator has 750 sections. The combined sets can safely be run for an hour or so at a load of as much as 1900 kilowatts.

The second engine drives a dynamo of the same output, made by the British Schuckert Electric Company, Ltd. The machine is of the company's normal outer-pole type in which the stationary field magnets are arranged in the form of a frame, on the inner side of which the actual magnet poles project radially. The machine is designed for a normal output of 697 kilowatts at 570 to 600 volts when running compound at 230 revolutions per minute. The maximum output for two hours is 940 kilowatts at 510 volts, or 1150 kilowatts at 600 volts.

The armature is slot-wound, in accordance with the Glasgow Corporation requirements. The magnetic field between the armature and pole-pieces is so proportioned that the armature reaction is reduced to a minimum, and thus a small displacement of the brushes is of no importance. The magnet frame is in two parts, the joint being in the horizontal axis; the top half is provided with a lifting attachment, and is easily removable for inspection of the armature. The weight of the whole machine is twenty-six tons.

At the close of the Exhibition these two sets will become the property of the Glasgow Corporation, and will be removed to one of their electric lighting stations, where Willans engines to the extent of about 14,000 H. P. are already installed.

The fine pair of horizontal engines with generator shown in Fig. 3 constitute the joint exhibit of Messrs. Robey & Co., Ltd., of Lincoln, and Messrs. Mavor & Coulson, Ltd., of Glasgow. The engine beds are of a pattern now extensively used by Messrs. Robey for tramway and motor work, the chief feature being the broad, spreading foot, almost amounting to a platform, cast in one piece with each main plummer-block. These massive castings are bored and faced to receive the flange and circular projection, or "dowel," of the tubular trunk guides, which, as will be seen, form the sole connection between main bearings and cylinders. The exceeding simplicity and "straightforwardness" of this design cannot fail to commend itself to everyone imbued with a true sense of the fitness of things. Crosswise, these two plummer-block castings are connected by cast-iron stretcher-plates, forming an accurate and rigid base for the heavy casting of the magnet ring.

The crankshaft, which, besides the armature, carries a 16-foot fly-wheel weighing nearly twenty one tons, is of steel, 17¾ inches in diameter at the centre, with journals 12 by 24 inches. The bearings are, as in all the Robey horizontal engines, in four parts, dovetailed together to form a solid bush, and firmly secured laterally by side wedges and vertically by the cap of the bearing. The material of the bearings is cast iron, lined with Babbitt metal, and each one has its own oil-circulating pump, by which a continuous stream of lubricant is forced between the fixed and revolving surfaces, passing through a filter on its way round again. For particulars of the Robey valve gear the reader is referred to an article on "Typical Horizontal British Steam-Engines," contributed by the writer to this magazine for May, 1900.

The exhaust valves are flat gridiron or multiple-ported slide valves, placed horizontally. The steam exhausted from the high-pressure cylinder is reheated on its way to the low cylinder by a spiral coil filled with steam at boiler pressure in a "hot-pot," or intermediate receiver. Both cylinders are

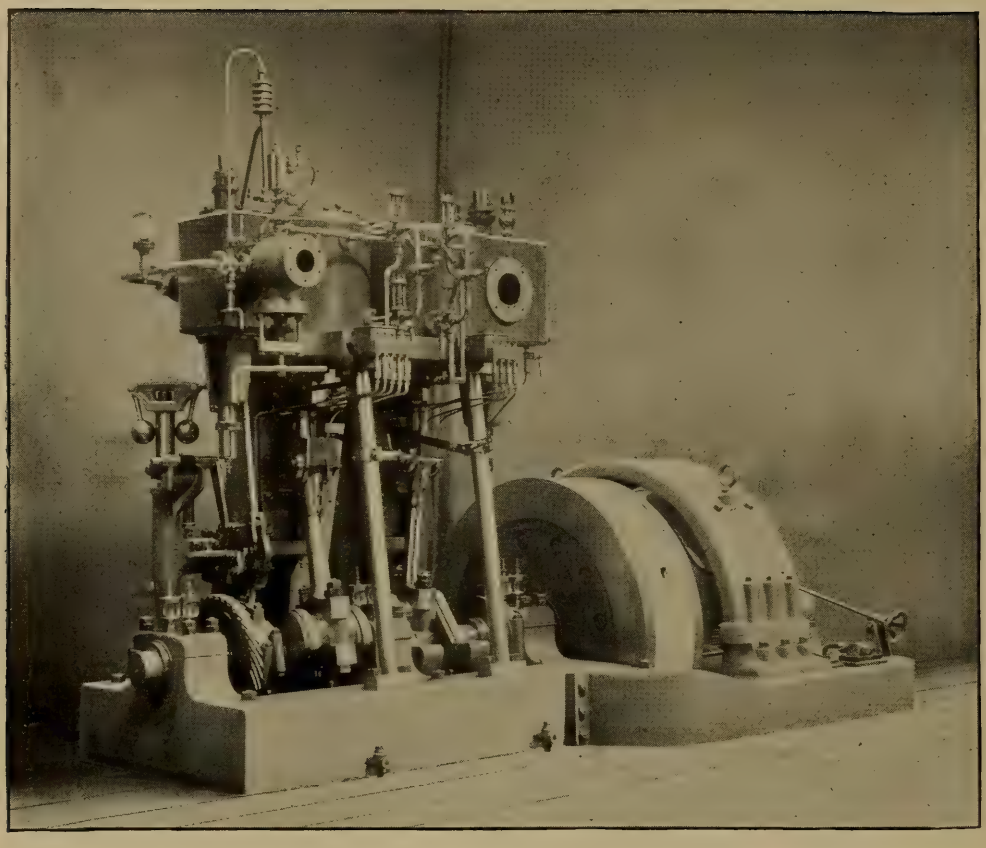


FIG. 4.—OPEN-FRONT ENGINE BUILT BY MESSRS. ROBEY & CO., LTD., LINCOLN

steam-jacketed. The engine has 20 and 35-inch cylinders, with 42-inch stroke, and makes ninety revolutions per minute, the maximum load being 650 I. H. P. The steam consumption (non-condensing) is seventeen pounds of steam per I. H P. per hour at full load, and the combined full load efficiency is 86 per cent.

The makers of the generator, Messrs. Mavor & Coulson, Ltd., say that this is the largest machine of the kind hitherto constructed in Scotland. It is mounted directly upon the disc shaft of the engine, the armature boss, in addition to being keyed on the 17¾-inch shaft, being secured to the boss of the fly-wheel by four 3 inch steel bolts passing right through both. The machine is designed to give an output of 636 ampères at 550 volts,—350 kilowatts.

Messrs. Robey exhibit also two smaller vertical engines with generators by Messrs. Ernest Scott & Mountain, Ltd., of Newcastle. The larger of these in point of size is illustrated in Fig. 4, and is of their open-front type, with cylinders 10½ and 18¼ inches in diameter by 11 inches stroke, making 250 revolutions per minute, and giving 100 I. H. P. on a consumption of twenty-six pounds of steam per I. H. P. per hour. The fly-wheels of both these engines are of noticeable size and weight, the rotating masses in each case being calculated to absorb the irregularities in the turning movement to within one-two-hundredth of the normal.

In Fig. 4, as will be seen, the governor is driven by screw gearing, the driven wheel being of compressed leather, noiseless in working. There are two eccentrics, set respectively to give cut-offs of zero and three-fourths of the stroke, both coupled by very short rods to a slot-link, guided by radius-rods from a fixed point. The distributing valve is a double piston, without packing rings, but with large wearing surfaces, pierced by ports for both admission and exhaust. The governor controls this valve by shifting the posi-

tion of a radius-rod from the valve spindle relatively to the slot-link already mentioned. The lubrication of every part while running is provided for by a very complete system of oil distributing pipes from central boxes. Mounted upon a prolongation of the base-plate is the generator, which is of the shunt-wound type with an output of 200 ampères at 250 volts, in normal working.

The other Robey vertical engine (Fig. 5) has, like that just described, the oil being forced in at fifteen pounds pressure at the back of each crosshead slide, thus bearing the crosshead upon a film of oil. At the top and bottom of the stroke, ports, cut in the crosshead, admit oil to both ends of the connecting-rod at the instant when the reversal of pressure upon those important surfaces occurs. Separate pipes from the central reservoir conduct oil under pressure to every bearing in the engine, including the pins in the valve spindle joints.

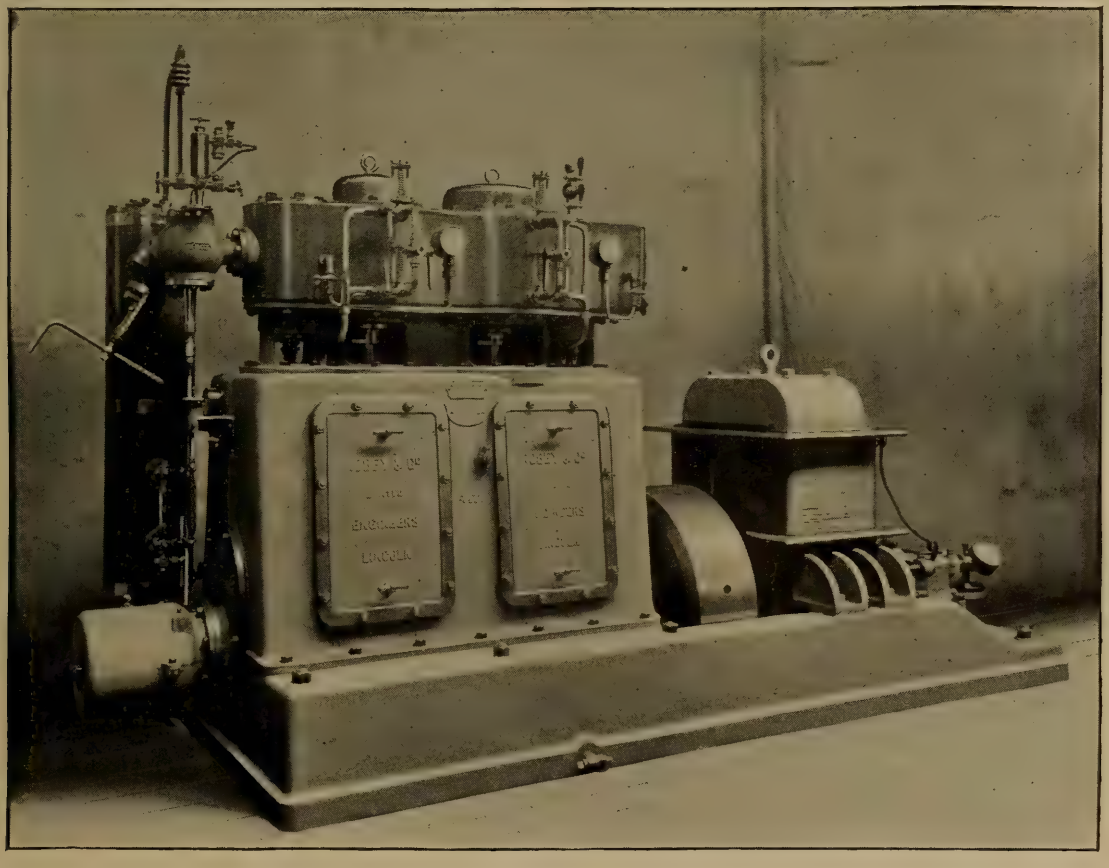


FIG. 5.—ENCLOSED VERTICAL ROBEY ENGINE AND SCOTT & MOUNTAIN GENERATOR

a piston valve on the high-pressure cylinder and a flat slide valve on the low-pressure cylinder. The governor, in this case, is mounted on the crankshaft and is enclosed (as are all the working parts of the engine) in a cast-iron casing. It acts directly upon a double-beat equilibrium throttle valve.

The system of forced lubrication employed is the Richardson-Wansbrough, the essential feature of which is that the crankshaft is not perforated, as usual,

As a proof of the efficiency of the lubrication, it may be mentioned that the first engine to which the system was applied was allowed to run on a day load for two years before being opened out for examination, and even then no wear was perceptible. The cylinders are 8½ and 14½ inches in diameter by 6 inches stroke, developing 100 I. H. P. at 550 revolutions per minute. The generator, on the same bed-plate, is also of Messrs. Scott & Mountain's

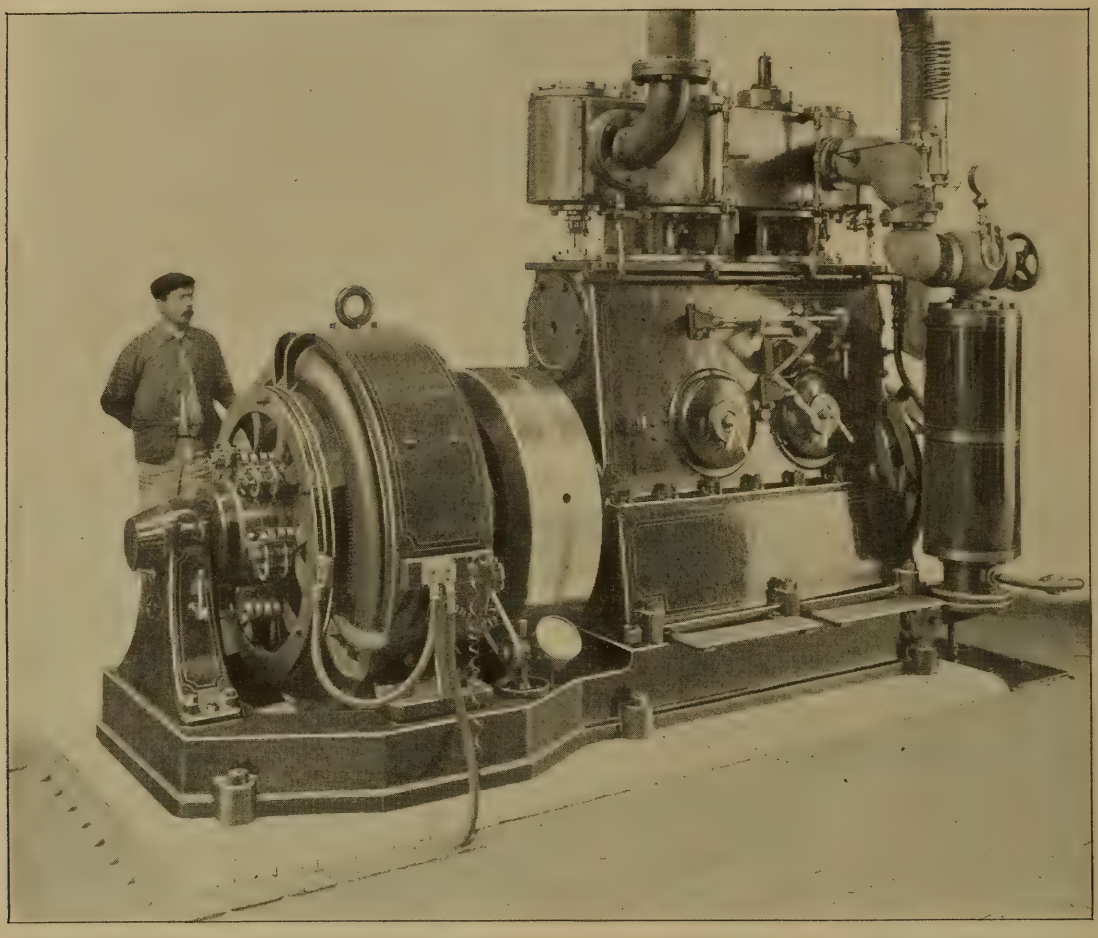


FIG. 6.—VERTICAL COMPOUND ENGINE BUILT BY MESSRS. RUSTON, PROCTOR & CO., LTD., LINCOLN

make. It is shunt-wound and is capable of giving 200 ampères at 250 volts at normal load.

Messrs. Ruston, Proctor & Co., Ltd., of Lincoln, contribute one of their high-speed, vertical compound engines, coupled direct to a continuous-current dynamo of their own make. Figs. 7 and 6 show, respectively, a vertical section, and the external appearance of the set. The cylinders are 9½ and 15 inches in diameter by 8 inches stroke, making 450 strokes per minute, and are both fitted with piston valves. The receiver pipe is made in the form of a belt around the cylinders, and the cross-head guides are cast in one piece with the cylinder covers, forming also the distance pieces between the cylinders and the casing of the engine.

This engine presents two features which are rather unusual in high-speed, forced-lubrication engines. The high-pressure piston valve is controlled by a crankshaft governor, thus giving an automatic cut-off in place of the usual throttle valve, and the two cranks are placed at right angles with each other instead of opposite, as is the usual practice. The makers state that they get a very uniform turning movement by the use of cast-iron counterbalance weights attached to the crank-cheeks, and that they have had a precisely similar set running for some time in their own works without any sign of undue wear having taken place, the whole of the working surfaces being found in good condition, smooth and highly polished.

The main bearing next the fly-wheel is in two parts, and the eccentric for the low-pressure piston valve is placed between them. The whole of the working parts are enclosed within the casing, doors in the front and at the ends affording easy access to every part of the interior. The oil pump is placed outside the shaft governor, and is of the oscil-

lating, valveless type, circulating the oil from the bottom of the bed-plate through a strainer continuously to all the moving surfaces.

A large separator is placed immediately underneath the stop valve, and is fitted with an ejector to rid it of the condensed water. The fly-wheel is heavy, and forms the coupling to the dynamo, which is of the multipolar type, constructed to give a maximum output of 80 kilowatts at 250 volts. The dynamo has a circular cast-steel frame, is compound-wound, and is provided with a regulating resistance connected with the shunt coils by which the E. M. F. can be slightly varied either way, independently of the engine speed. The engine and dynamo are both carried on one bed-plate, and the whole is neatly and compactly arranged and finished throughout in good style.

The exhibit of Messrs. Ernest Scott & Mountain, Ltd., of Newcastle-upon-Tyne, consists of the combined high-speed engine and dynamo shown in Fig. 8. This set comprises one of their well-known, enclosed, forced-lubrication engines for direct coupling, the dimensions and capacity of which are as follows:—Cylinders, 11¼ and 21 inches by 10 inches stroke; revolutions per minute, 360; brake horse-power with 140 pounds pressure at stop valve, 240. The cylinders are mounted upon the cast-iron box forming the crank-cham

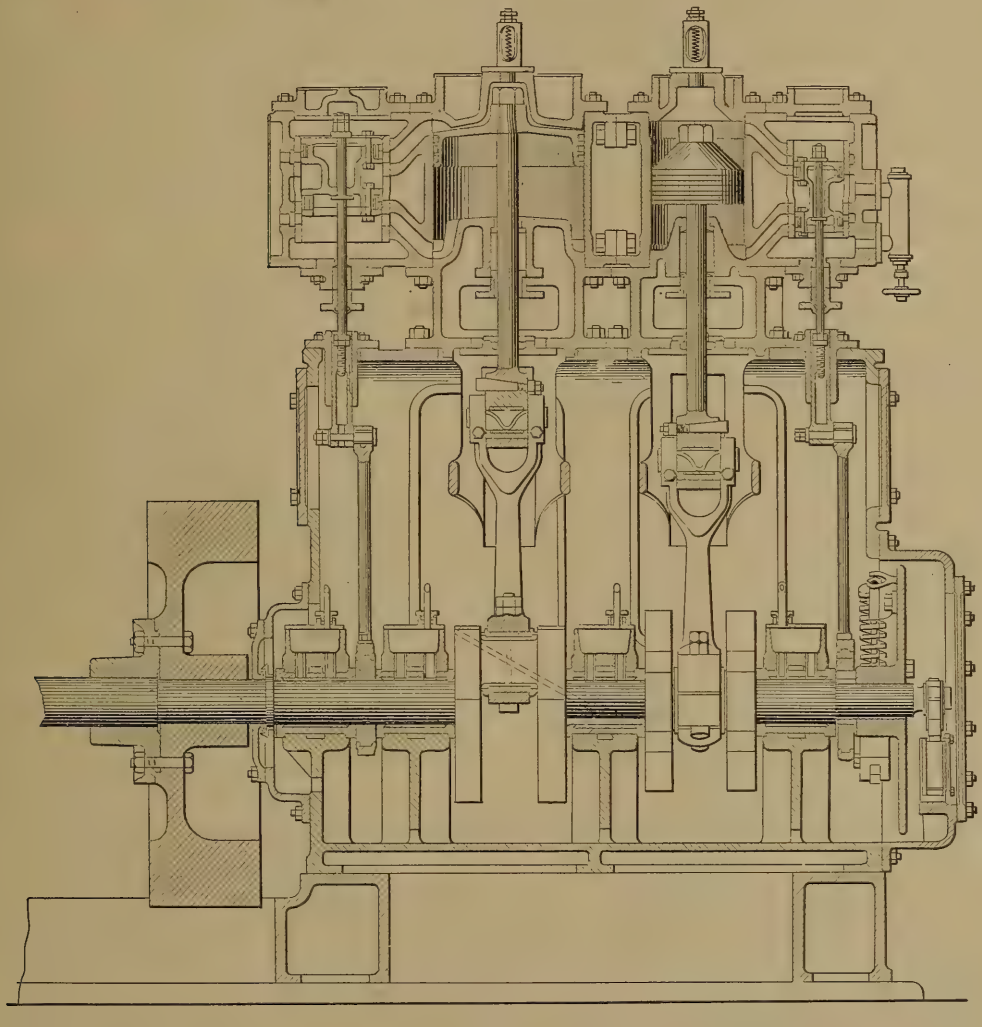


FIG. 7.—A VERTICAL SECTION OF THE ENGINE OPPOSITE

ber from which they are separated by distance pieces with enlarged holes for giving access to the glands.

The steam distribution is controlled by a central piston valve which admits and exhausts the steam for both cyl-

inders by the agency of a single eccentric. The steam chest for the piston valve is fitted with a separate liner of specially hard cast iron, having the ports cut through it. A steam separator of ample capacity is fitted close to the stop valve. The oil is prevented from travelling along the crankshaft, either to the governor or to the dynamo, by special oil-throwers secured to the crankshaft at either end, the oil flying to a drip-ring which returns it to the crank-chamber. The governor is mounted upon the end of the crankshaft and controls the engine by means of an equilibrated throttle valve, and has also a hand adjusting gear by which the speed of the engine can be altered while running.

The direct-coupled dynamo is of Messrs. Scott & Mountain's four-pole, continuous-current type, giving, with 360 revolutions per minute, an output of 273 ampères at 550 volts, or 150,150 watts.

Messrs. Alley & Maclellan, of Glasgow, show a three-crank, single acting, vertical engine (Fig. 9), compounded tandem-wise, coupled to a Mavor & Coulson dynamo. This interesting engine much resembles the Willans type so far as the steam cycle is concerned. Instead, however, of the valves being central and contained within a hollow piston-rod, they are placed alongside the cylinders, as shown in Fig 9, representing one of the three tandem engines in section.

The steam enters at the top, first passing through a separator, and flows round the circumferential recess in the piston valve, thence to the upper side of the high-pressure piston. In Fig. 9 the piston is ready to begin its downward stroke, and the valve has just begun to uncover the port. The exhaust

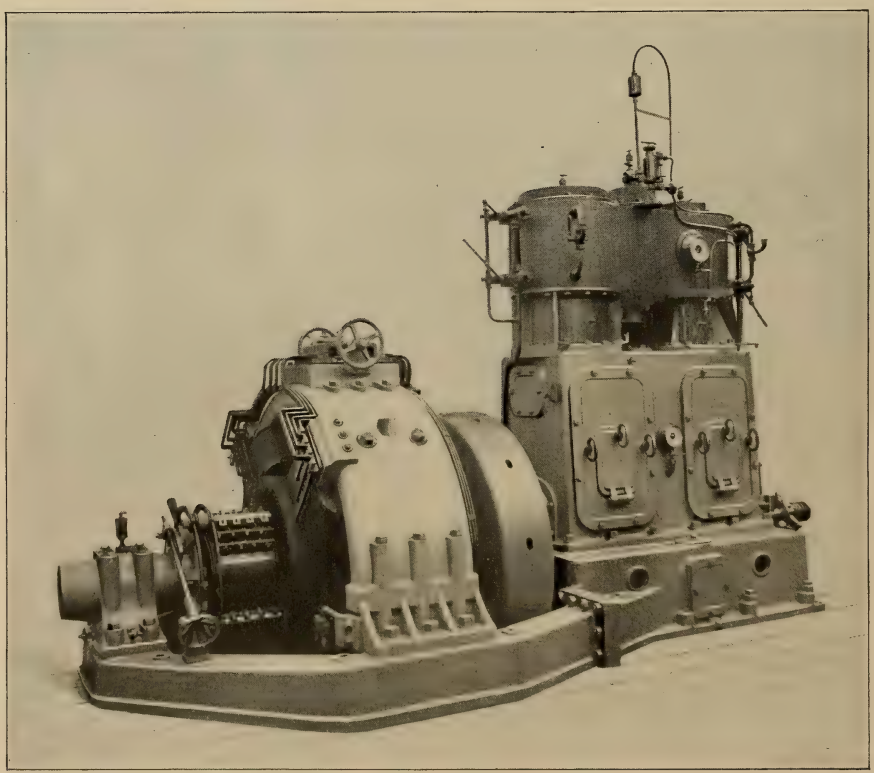


FIG. 8.—HIGH-SPEED ENGINE AND DYNAMO BUILT BY MESSRS. ERNEST SCOTT & MOUNTAIN, LTD., NEWCASTLE-ON TYNE

is controlled by the lower edge of the piston valve, and the once-used steam, in its turn, enters the low-pressure cylinder by a very direct passage shown just uncovered by the top edge of the low-pressure piston valve.

But to return for a moment to the high-pressure cylinder. A number of small holes will be noticed near the bottom. These are so placed that they are just uncovered by the piston when it reaches the bottom of its stroke, and through them the condensed water is enabled to pass into the surrounding receiver. Aided by the conical formation of the piston, the cylinder is thus instantly cleared of water. During the upward stroke, until the exhaust closes and compression begins, the high-pressure piston is in equilibrium, both sides being in communication with the receiver.

The low-pressure cylinder exhaust is regulated by the lower edge of its piston valve, and the drainage holes of the high pressure cylinder are here replaced by a series of shallow inclined grooves, enabling the water of condensation to pass by the piston when the latter is at the bottom of its stroke.

There is a third cylinder and piston, below the low-pressure cylinder. This is, very much as in the Willans engine, simply a cylindrical trunk guide, the piston being in reality the crosshead, but serving a double purpose in also compressing the contained air above it, thus ensuring that the connecting-rod upper brass shall never leave the crank-pin.

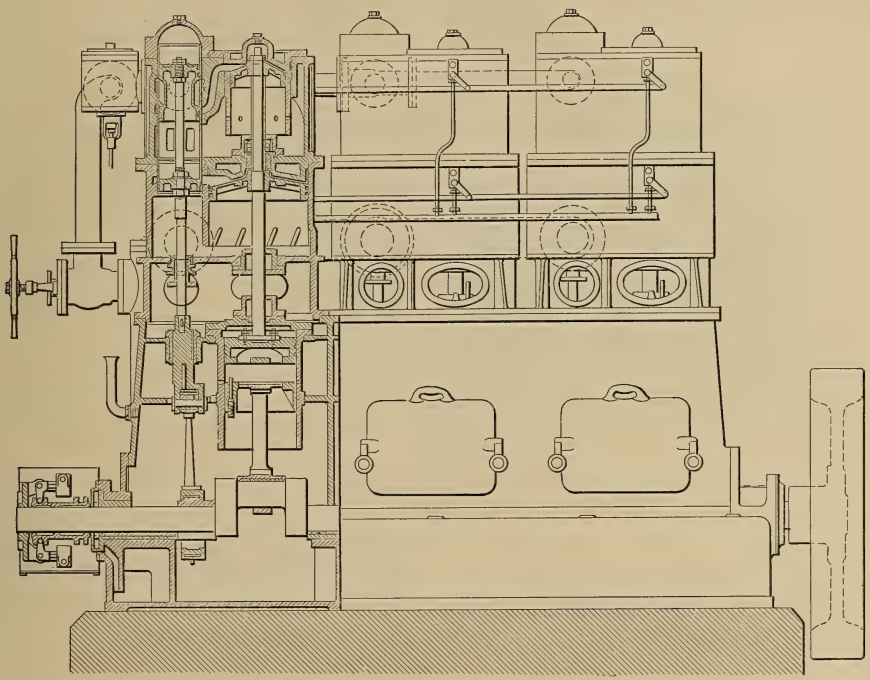


FIG. 9.—THREE-CRANK COMPOUND SINGLE-ACTING ENGINE BUILT BY MESSRS. ALLEY & MACLELLAN, GLASGOW

The engine, with its three pairs of 10 and 18-inch cylinders, runs smoothly and silently at 400 revolutions per minute, the stroke being 9 inches, and the cranks, of course, 120° apart. The governor, seen mounted on the end of the crankshaft, controls the speed by an equilibrium throttle valve, the admission in the high-pressure cylinder being constant at about half stroke. The

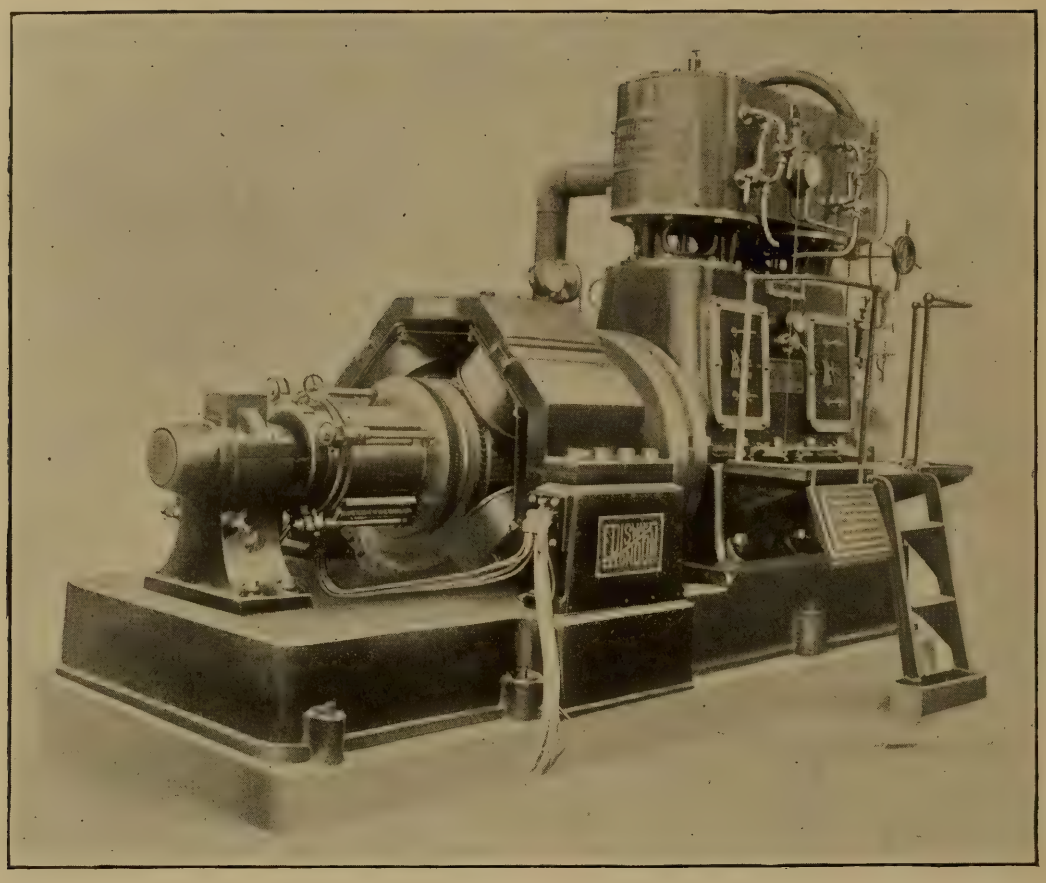


FIG. 10.—COMPOUND ENGINE BUILT BY MESSRS. BROWETT, LINDLEY & CO., LTD., PATRICROFT, MANCHESTER

connecting-rod "brasses" are of cast steel, lined with white metal, the main bearings being of cast iron, the lower halves only being lined with the white metal.

Messrs. Mavor & Coulson's dynamo, coupled to this engine, is a six-pole machine similar in design to the larger one exhibited in connection with the Robey horizontal engine already described. The output is 680 ampères at 265 volts, equal to 240 electrical H. P. In mounting this dynamo and engine the usual combination base-plate has been dispensed with, and in its place three cast-iron anchor plates are built into the foundations for carrying the magnets and the outer bearing of the dynamo. This arrangement affords more ready access to any part of the dynamo, and also allows greater freedom for the circulation of air. In these respects the arrangement has advantages over the box form of bed-plate commonly used in such cases.

Messrs. Browett, Lindley & Co., Ltd., of Patricroft, Manchester, show one of their compound, self-lubricating vertical engines, direct-coupled to an Edison-Swan dynamo of 130 kilowatts capacity at 380 revolutions per minute. It is illustrated in Fig. 10. The cast-iron frame or crank-chamber is fitted with a water casing on its top surface for the purpose of intercepting the heat from the cylinders tending to raise the temperature of the crank-chamber. This is an improvement which the writer has not noticed in any of its fellows at the Glasgow Exhibition. The bored-out guides for the crossheads are cast in one piece with the distance pieces which afford access to the glands without entering the crank-chamber.

The steam joints about the cylinders are all scraped or ground to a true metallic fit, and an ample provision of bolts and studs secures that these joints shall be permanently steam-tight. The high-pressure piston of cast iron and

the low-pressure piston of cast steel, for the sake of equality of weight, are each fitted with two cast-iron, steam-expanded packing rings, sprung into place to avoid loose cover plates in the pistons. The rods, of steel, are ground up to a true cylindrical form, and are fitted to the pistons by a cone and shoulder, secured by a large nut.

Each cylinder has a piston valve, driven by separate eccentrics, that for the low-pressure cylinder being placed in the centre of the divided middle bearing. The usual crankshaft governor, controlling the speed through an equilibrium throttle valve, is used, and the oil-forcing pump is of the oscillating, valveless type, distributing the oil under pressure to every bearing and pin throughout the engine. The dimensions of the cylinders are, high-pressure, 13 inches diameter; low-pressure, 21 inches diameter; stroke, 9 inches. The speed is 570 feet per minute.

The four-pole "Ediswan" dynamo coupled to this engine is intended for an output of 520 ampères at 250 volts, with 380 revolutions per minute. The guaranteed efficiency is 94 per cent. at full load, and 91 per cent. at half load.

Messrs. D. Bruce Peebles & Co., Tay Works, Edinburgh, exhibit a considerable amount of electrical machinery distributed about the building. Much of this naturally falls outside the scope of the present article. Among the generating sets is the 250-KW dynamo, direct-coupled to a 350-H. P., triple-expansion Bellis & Morcom engine, shown in Fig. 11. This set is stated to be eminently adapted for power work. It is a compact and well-finished machine, and a credit to the builders. Messrs. Bellis & Morcom's type of enclosed, self lubricating engine is too well known to need description here, particularly as this type was fully described and illustrated in this magazine so recently as February of the present year. Messrs. Davey, Paxman & Co., Ltd., of Colchester, have on view a very handsome compound horizontal engine, carrying on the crankshaft the armature of a traction generator by the Electric

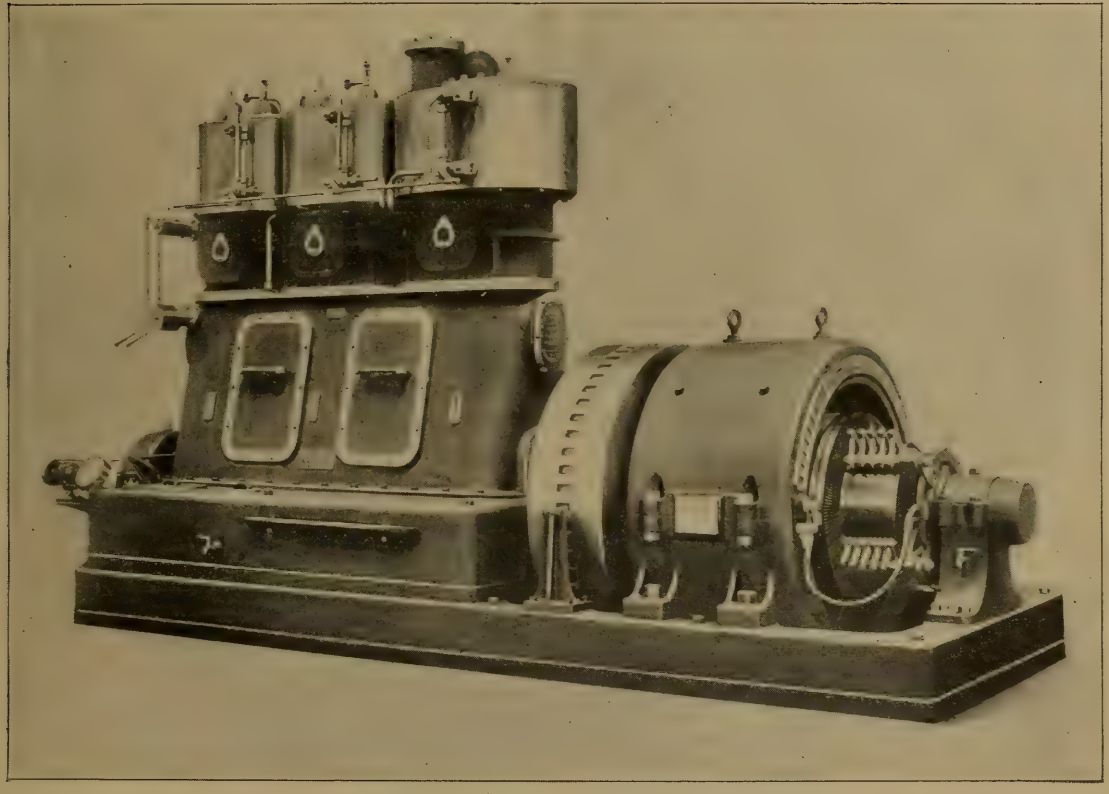


FIG. 11.—TRIPLE-EXPANSION ENGINE BY MESSRS. BELLIS & MORCOM, LTD., BIRMINGHAM, DRIVING A DYNAMO BUILT BY MESSRS. D. BRUCE PEEBLES & CO., EDINBURGH

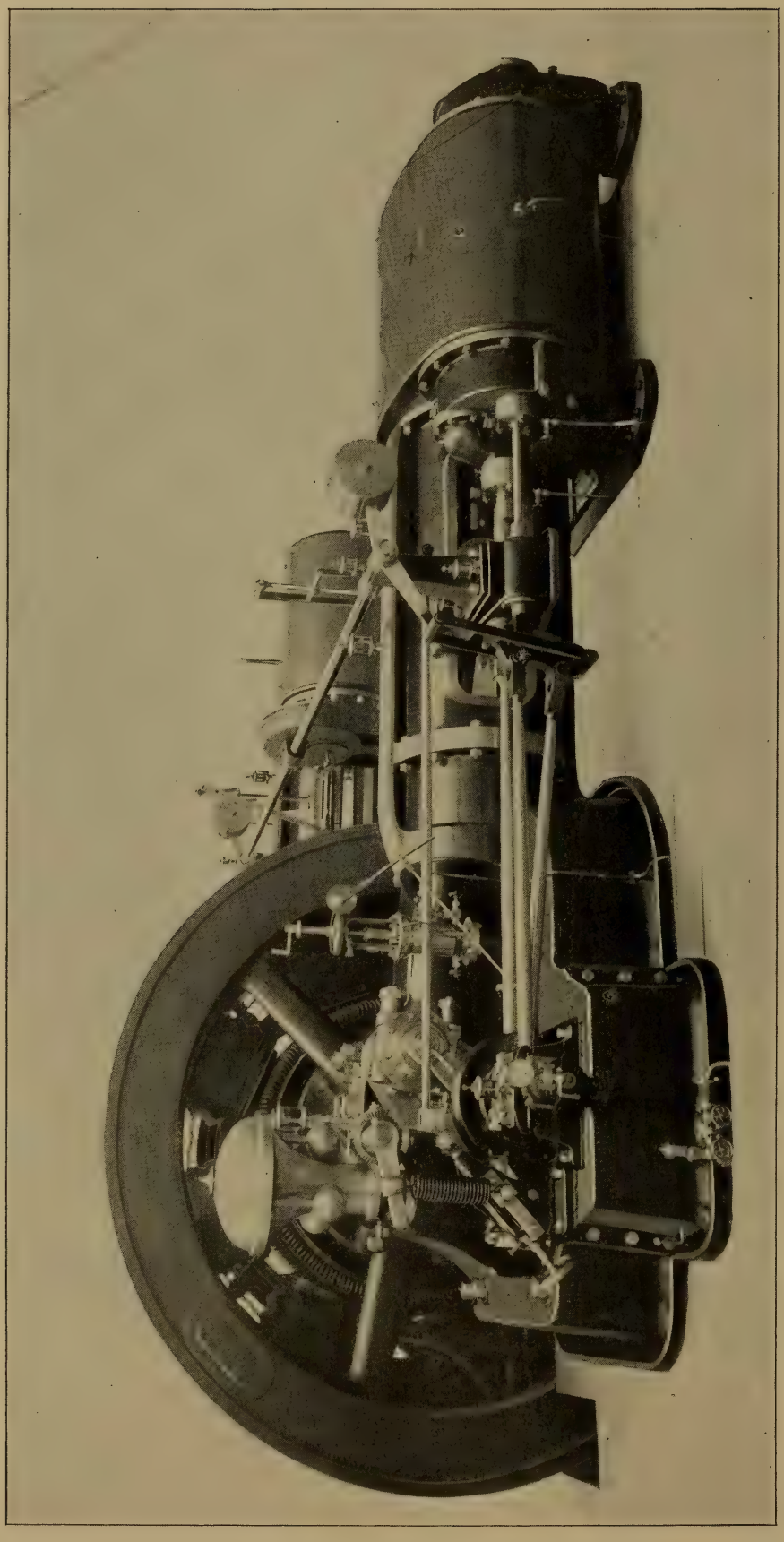


FIG. 12.—COMPOUND ENGINE BUILT BY MESSRS. DAVEY, PAXMAN & CO., LTD., COLCHESTER

Construction Company, Ltd., of Wolverhampton. It is shown in Fig. 12. The cylinders are 15½ and 27 inches in diameter by 30 inches stroke, and the engine runs at 150 revolutions per minute, or 750 feet piston speed. The bed-plates proper, carrying the massive main bearing plummer-blocks, are extended laterally for the double purpose of carrying the valve eccentric shafts and of providing a broad and spreading base for the main bearings. A cylindrical extension of the bed-plates to which the trunk guides are bolted provides a direct and rigid connection with the cylinders.

This method of construction is an eminently suitable one for engines of this class, *i. e.*, where the valves are worked by eccentrics in the axis of the crankshaft. It allows of the main bearings being placed much closer together than would be the case if the eccentrics were placed upon the main shaft. In the engine shown the centres are only 8 feet 6 inches apart. The eccentrics, being carried upon subsidiary shafts of small diameter, are small and compact, and the cylinder ports may be as short as desirable, there being no long main bearing separating the cranks and eccentrics.

The valves are pistons. In the high-pressure cylinder there are two, the main and the expansion valves. There are two main valves to the low-pressure cylinder and one expansion valve. They are worked by a link gear, the two ends of each link being moved respectively by eccentrics set for the minimum and maximum points of cut-off. The governor is of the three-ball, pendulum type, driven by screw gearing from the eccentric shaft, and acts upon both sets of valve gear, thus maintaining a constant receiver pressure at all points of cut off. An ingenious speed adjuster regulates the number of revolutions to be maintained, the adjustment being, of course, made while the engine is running.

The engine is suitably equipped for the use of superheated steam of the highest temperatures (at 650° Fahr. in the Exhibition), and is provided with an interheater between the cylinders, fed with boiler pressure steam, highly superheated, to raise the temperature of the high-pressure exhaust steam above saturation temperature before entering the low-pressure cylinder. The low-pressure exhaust is passed through a feed-water heater. The engine is highly finished, an unusual amount of bright work being introduced into the design.

The electric generator exhibited in combination with it is by the Electric Construction Company, Ltd., and is their standard 500-kilowatt machine, of the high-speed type, but wound, in this case, for a speed of 150 revolutions per minute, giving an output of 300 KW at the usual electric traction E. M. F. of 500 volts, and over-compounded 10 per cent.

This plant is driven by one of Paxman's "Economic" boilers, working in conjunction with Paxman's superheater; and in the rear is placed one of Green's economisers to utilise the otherwise wasted heat escaping from the boiler and super heater. The "Economic" boiler does not require detailed description, for its use in electrical and other installations is widespread. The superheater is placed alongside the boiler, and is so connected with the main steam pipe that the engine can be run with either saturated or superheated steam. The superheater is composed of seven elements, each consisting of one divided header, the compartments of which are connected by a series of single-loop tubes extending into the superheating space. The headers are connected together by elbows in the rear; and the steam is compelled to flow through the superheating chamber to and fro seven times. The superheater is independently fired with coke or anthracite coal, and has the flues arranged so that the tail gases can be delivered either under the boiler, and thence through the Green economiser to the chimney, or direct to the economiser or to the chimney.

Messrs. Babcock & Wilcox, Ltd., contribute three boilers to the steam generating plant at the Exhibition.

Two of them are of their land type, whilst the third is of their latest marine pattern. The former are set together in one battery and are fitted with the considerable heating surface. Prevention against overheating during steam raising is ensured by an arrangement by which the superheater tubes are

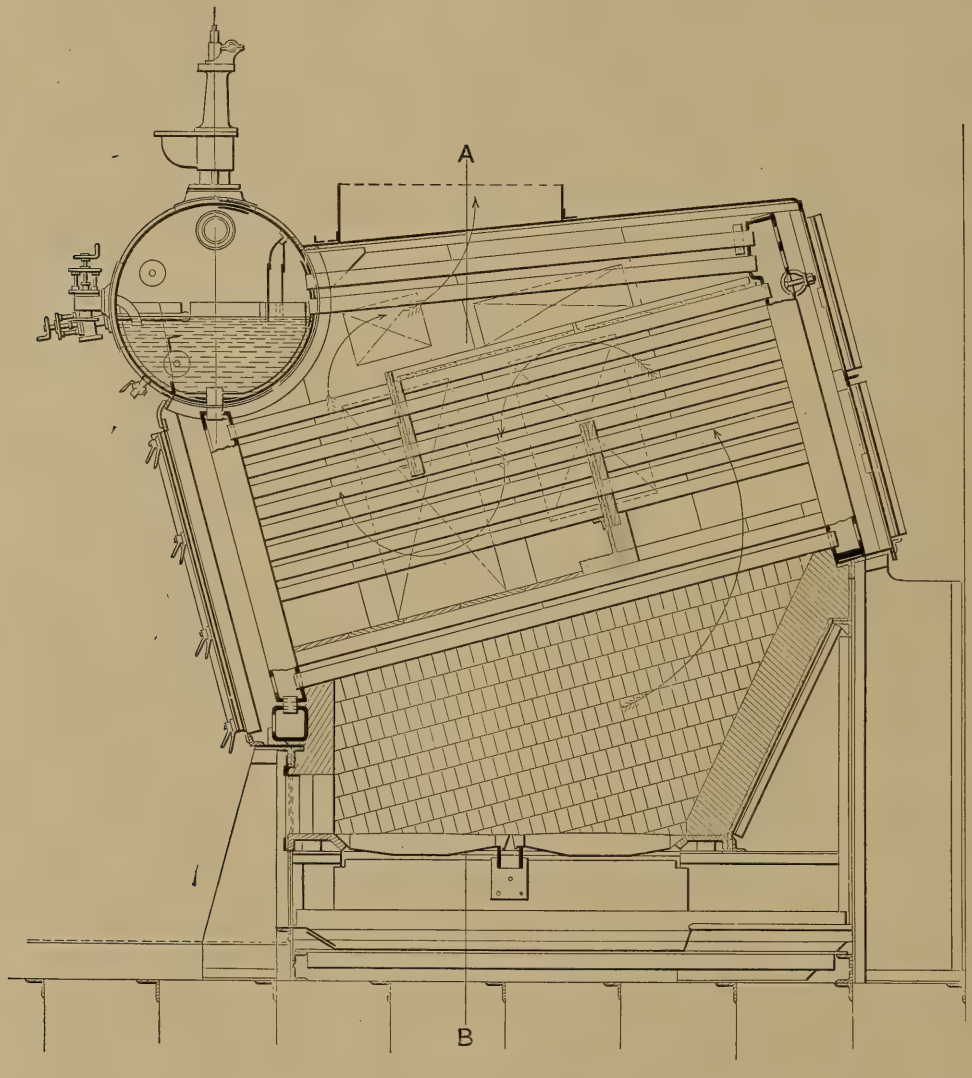


FIG. 13.—MARINE BOILER MADE BY MESSRS. BABCOCK & WILCOX, LTD., RENFREW, SCOTLAND

Babcock & Wilcox steam superheater, a section of which is shown in Fig. 14. It may be described shortly as an arrangement of U-shaped tubes connected at both ends with "manifolds," one of which receives the natural steam from the boiler, the other collecting the superheated steam after it has traversed the superheater tubes and delivering it to the valve, placed above the boiler. The superheater is not subject to the immediate action of the fire, as the furnace gases must first pass through the front part of the boiler, which comprises a flooded with water, so as to form a continuation or appendix to the ordinary heating surface while steam is being raised, or if it is desired to use the steam in the saturated state. From 100° to 150° of superheat are usually provided in the proportions adopted by Messrs. Babcock & Wilcox, and an intelligent use of the superheaters goes a long way to assist engineers in attaining the ideal consumption of one pound of coal per horse-power per hour.

Another highly interesting adjunct is fitted to these boilers,—the Babcock &

Wilcox chain-grate mechanical stoker, of which particulars have previously been given in this magazine.*

The Babcock & Wilcox marine boiler, also in steam at the Exhibition, is illustrated in Fig. 13. It is made entirely of wrought steel, and consists of straight tubes, forming the heating surface, divided into vertical sections and placed at an angle of 15° to the horizontal. These tubes are expanded at each end into wrought-steel staggered headers with an ordinary boiler tube expander.

The horizontal steam and water drum is placed at the front of the boiler, above the lower end of the inclined tubes, connected underneath to the downtake headers by short vertical tubes, and to the uptake headers by horizontal tubes.

The mud-drum, extending the whole width of the boiler, is fixed to the bottom of the downtake headers by short forged steel cap and nut, the joint being made on the inside.

Surrounding the pressure parts, and firmly bolted to the foundations, is a structural iron framing to which the casing plates are fastened. The sides of the furnace are composed of fire tiles, the whole structure being surrounded by removable wrought-iron casings, lined with non-conducting composition. Hinged doors are fitted to the casing at front, rear, and sides to admit of access to the hand-hole fittings, and for the removal of soot.

There are two Stirling water-tube boilers in use at the Exhibition. One of these is shown in course of construction in Fig. 15. The space bounded by the steel channel frame is the combustion chamber, to be completed by the filling in of the brickwork, as shown in Fig. 16. It will be seen of what relatively considerable size this is, com-

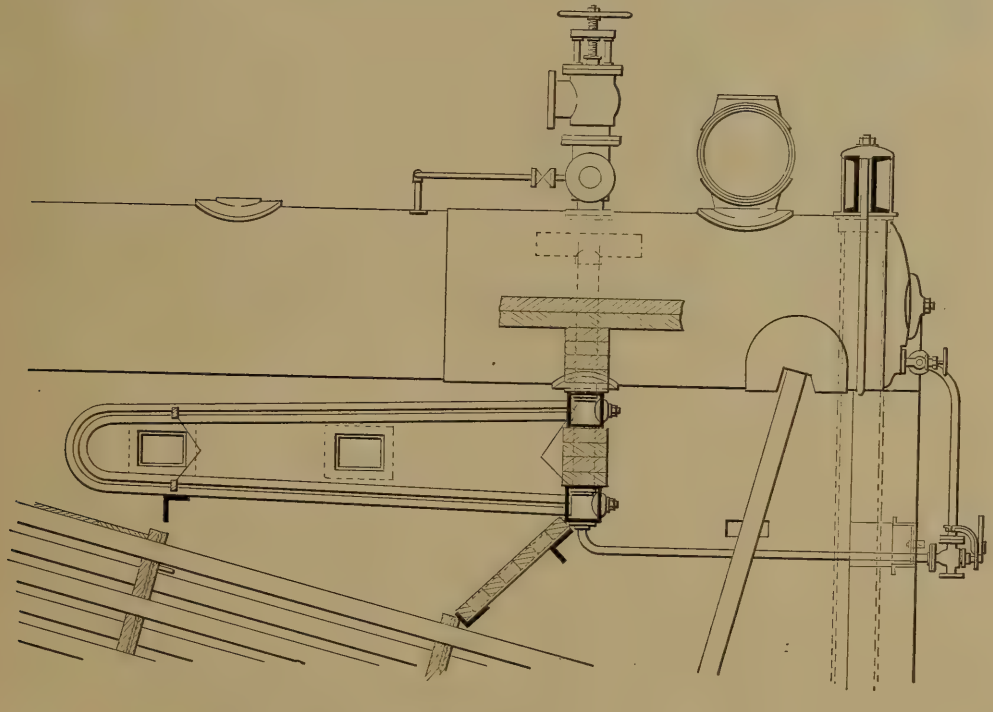


FIG. 14.—THE BABCOCK & WILCOX SUPERHEATER

tubes. Hand-holes are arranged opposite to the end of each tube, to permit of its being cleaned or renewed, each hand-hole being closed by a forged steel plate, faced, and drawn to its seat by a

pared with the grate area. The makers claim an important advantage in the thorough combustion of the fuel, aided by the reflected heat from the solid brickwork, and the zigzag course the heated gases are compelled, by diaphragms, to travel in, around and amongst the tubes. Briefly, the boiler consists of three

* See CASSIER'S MAGAZINE for February, 1898, containing a long article on "Mechanical Stokers: Their History and Development," by William R. Roney.

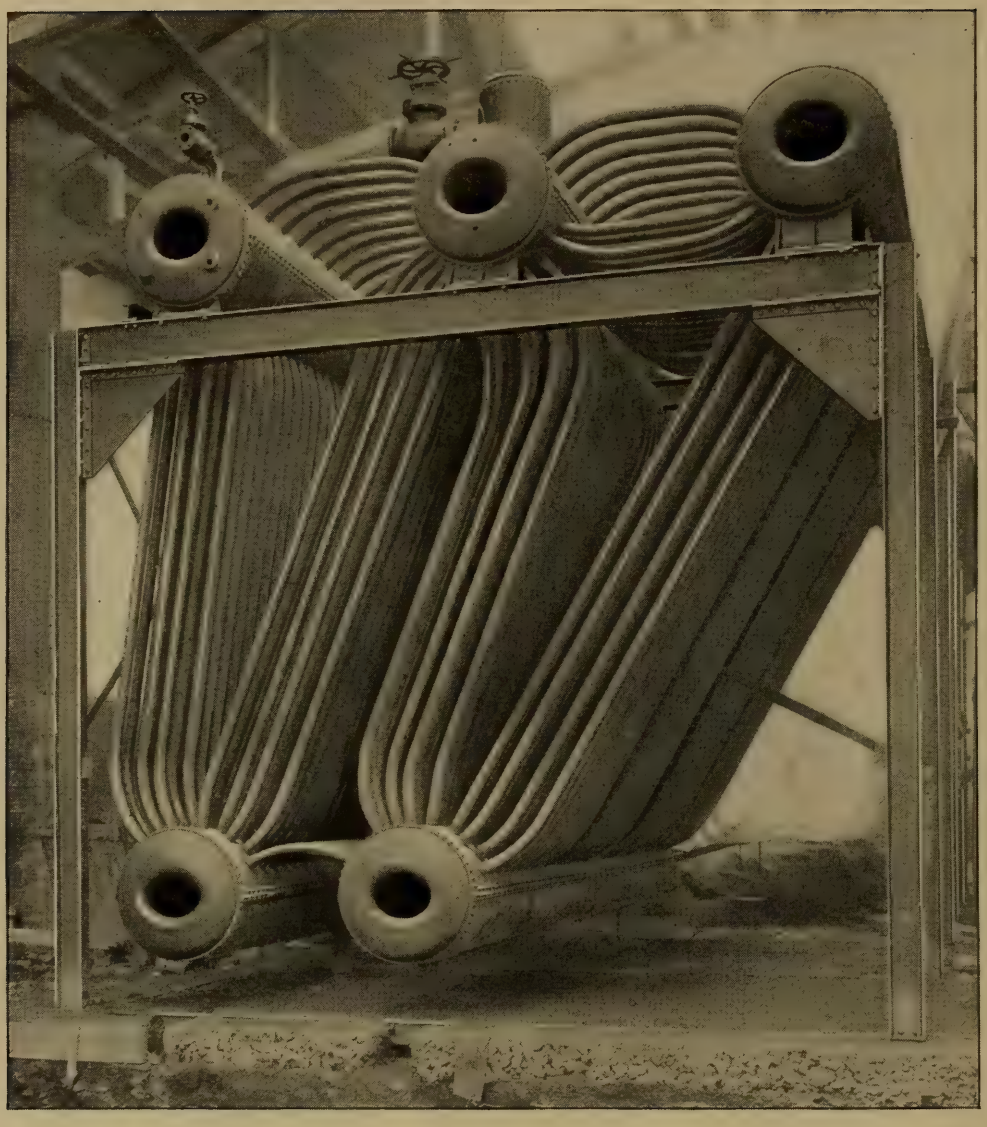


FIG. 15.—STIRLING BOILER IN COURSE OF ERECTION AT THE GLASGOW EXHIBITION

overhead drums, set at slightly different levels, the water surface being highest in the third, or rearmost, drum. Four ranges of inclined tubes, disposed in almost the form of an italic *w*, connect these with, and carry the weight of, two mud-drums, placed at the back of the fire-bridge, each series of drums being also linked together by short, curved tubes. The arrangement of the tubes does not, at sight, suggest the actual course of the circulation. The makers, however, from experiments made with models fitted with glass tubes and glass ends to the drums, have been able to demonstrate that the circulation actually does take place in the manner prescribed, and the success of the Stirling boiler as a steam-producer appears to substantiate their claims.

Referring now to Fig. 16, the feed-water inlet is situated at the top of the rearmost drum. The cold water passes down the back row of tubes, thus coming in contact with the escaping furnace gases and robbing them of the last available heat. This back bank of tubes acts, in fact, as an economiser, or feed-heater. It has also another function. Being isolated from the general circulation of the boiler, there is a slow current upwards in the tubes nearest the fire and downwards in the back rows. The feed-water, becoming heated to a high temperature, deposits its suspended matter in the back lower drum, and passes onward to the front lower drum, practically purified of its scale-

forming constituents. The course of the circulation is upward and rapid in all the tubes of the front bank, more slowly downwards in the second bank, and again more slowly downwards in the third bank. The greater part of the water brought down by the third bank passes from the back lower drum through the short, curved tubes to the front lower drum, the remainder going to maintain the slow separate circulation in the back bank of tubes as already described.

The circulation begins as soon as the fire is lighted (except in the economiser portion); steam begins to form in the front section, and the rapidity of the circulation continues increasing as the temperature rises. There is no change in the direction of the current, only an augmentation of the speed, which is always greatest in the front tubes, less in the next bank, and less again in the third bank, very much in the ratio of the temperatures of the gases by which they are respectively surrounded. From this it follows that the deposit of scale, which is inversely proportionate to the speed of the current, is greatest in the back rows of tubes, and practically non-existent in the front rows which are exposed to the full heat of the furnace. The drums are all accessible through good sized manholes, and the tubes, which are 3¼ inches in external diameter, are simply expanded in place.

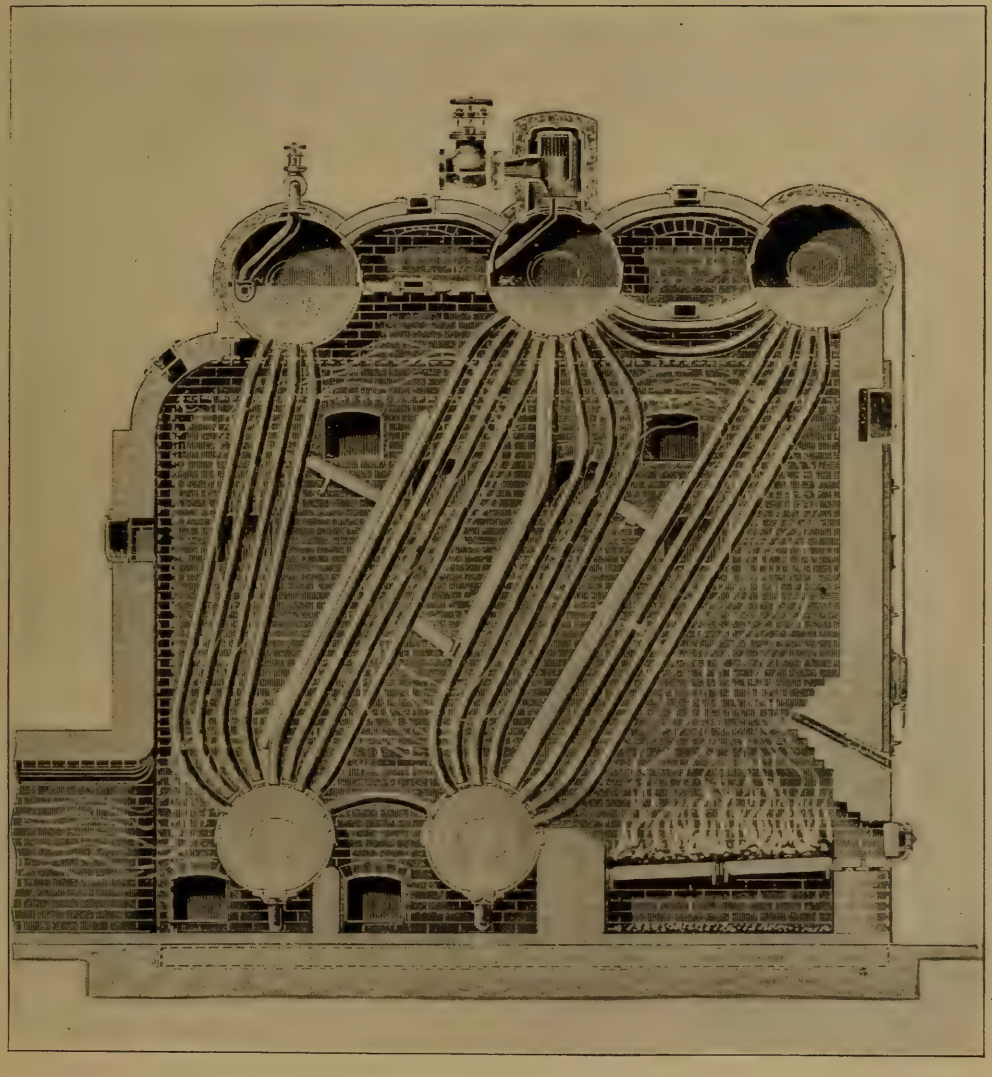


FIG. 16.—THE STIRLING BOILER. MADE BY THE STIRLING BOILER CO. LTD., EDINBURGH

The whole of the steam power for Exhibition purposes, outside the electric lighting plant, is derived from the

boilers of one firm, Messrs. Penman & Co., of the Caledonian Iron Works, Glasgow. This fine exhibit consists of four Lancashire boilers, 30 feet long by 8 feet in diameter, intended for a safe daily working pressure of 120 pounds. They are made of Siemens-Martin steel of selected quality, each ring of the shell being formed of one plate only. The longitudinal seams are butt-strapped inside and out with four rows of rivets, the circular seams being lap-jointed and double-riveted. The flues are 3 feet 3 inches in diameter, tapering, at the second last ring from the back, to 2 feet 9 inches in diameter, the last ring being cylindrical, at that diameter. They are made on the anti-collapsive, flanged-seam principle, thus removing all rivet heads, double thicknesses, and edges of plates from the impact of the flame.

The boilers are fitted complete with all furnace and steam mountings of the highest class, and are thoroughly well finished throughout.

THE TOOL, THE MACHINE, THE MAN

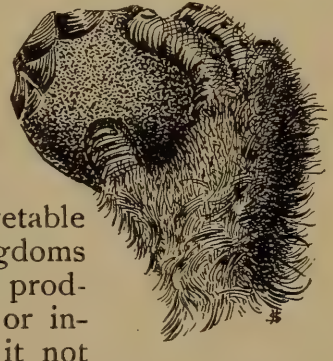
By W. H. Smyth

IT is well, once in a while, to look up from the bench, the machine or the drawing board, to straighten the back from the laying of bricks and turning of the soil, to lay down our tools, and thoughtfully and earnestly take a wider view. Only thus can we avoid the depressing influence of incessant routine; only thus can we realise that we are not mere cogs in an insensate machine, grinding and grinding without aim or purpose. From such a survey we can go back to our task with clearer vision and renewed courage,—courage born of the knowledge that each intelligent worker, far from being a mere inert fragment, pushed hither and yon by uncontrollable forces, is, in fact, a master force himself, controlling his own destiny, with the vast forces of nature but servants to do his bidding.

THE TOOL

Man's progress has proceeded not alone by a succession of infinitely small changes, but in this manner only up to certain epochs, or points of maximum possibility, and then by almost cataclysmic readjustments forming new starting points for other periods of growth, each of such readjustments being followed by an extended period of unusual activity and rapid progress. One of these epoch-making events occurred when our hairy and homely progenitor discovered the effectiveness of a stone to crack a cocoanut or the skull of a rival. In making this discovery, if he did not inaugurate the age of the tool, he at least prepared the way for it.

The immensities of time which elapsed during the stone ages indicate that the production and use of tools does not imply a high degree of reasoning intelligence, and that a high state of intellectuality is not a necessary consequence. There are in the modern machinist's kit no devices more perfect or more perfectly adapted to their uses than may be found in the offensive and defensive weapons of animals and in their constructive appliances. Nor are these devices essentially distinguishable from the tools of man otherwise than by the detachable character of the latter. Tools, in fact, are merely detached limb extensions of the human animal. This applies equally to the modern tool and to its paleolithic prototype, there being no essential difference between them. The advantages of the stone grasped in the paw having been stumbled on by the paleolithic pioneer of mechanics, the greater effectiveness of a sharp or pointed stone over a blunt or rounded one would have a double selective influence. It would tend to survival of its user and act as an effective discourager of the other, upon whom it was used. Is it not, therefore, more reasonable to consider the tool as an outcome of the same class of laws which have brought about the various offensive and defensive devices of the vegetable and animal kingdoms rather than as a product of reason or intelligence? Is it not much more probable that awakening intelligence found the stone hammer grasped in the hairy, powerful, though not unskilled, paw, than that awakened intelligence put it there?

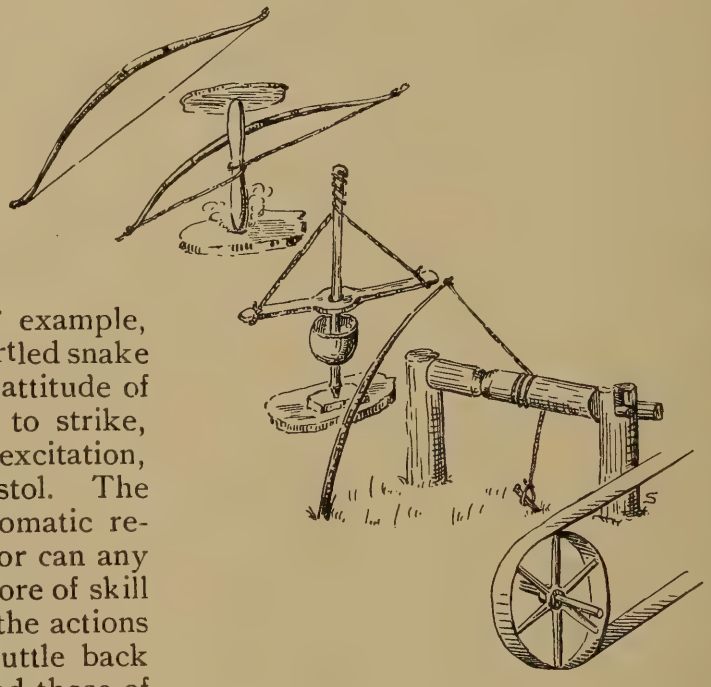


Skill may be considered as facility derived from repetition. Though skill is, in man, associated with intelligence and is probably a factor in its growth,

skill and intelligence are not essentially connected. Great skill may be obtained without a corresponding increase in intelligence. It would seem, in fact, that the highest expressions of skill occur disassociated from intellectual control. Skill in its most perfect exemplification is purely unconscious. This is seen in piano playing and many other forms of dexterity.

Any distinction which may exist between the human artisan and the animal using the appliance with which nature has furnished him does not relate to skill nor to the use of tools. No such distinction can be made, for example, between the actions of the startled snake when it throws itself into an attitude of defence and bares its fangs to strike, and a man, who, under like excitation, draws a knife, sword, or pistol. The acts of both are simply automatic reflexes of exterior stimuli. Nor can any distinction be made on the score of skill or the use of tools between the actions of a weaver throwing the shuttle back and forth across the warp and those of a spider forming her intricate web. These also express alike only facility, the result of repetition, that is, instinct

or habit both in the man and in the animal. It is only when the exercise of skill is diverted from its accustomed expression by predetermination towards a new end that a distinction arises. But to divert the expression of skill in this manner is impossible to a worker until he has attained a degree of intelligence which enables him to separate clearly his own entity from surrounding nature. Furthermore, this mental separation must be so complete as to permit of himself being a distinct subject for his



consideration. In other words, till he becomes definitely self-conscious. Then, and only then, do needs become wants. Only then does the previously acquired skill become available to satisfy his wants.

Though a need expresses a lack of adjustment to environment, and though all things animate, both individually and collectively, are subject to needs, there appears to be no inherent connection between a need and the things of which the lack causes the need, of such character that a need would tend to bring about its own satisfaction. A need may be so urgent, so imperative, that failure to supply it may entail the obliteration of individuals or even the extinction of a race, and still this urgent need would not of itself bring about its satisfaction except through the slow working of survival and elimination. Organisms which do not respond to needs do not survive.

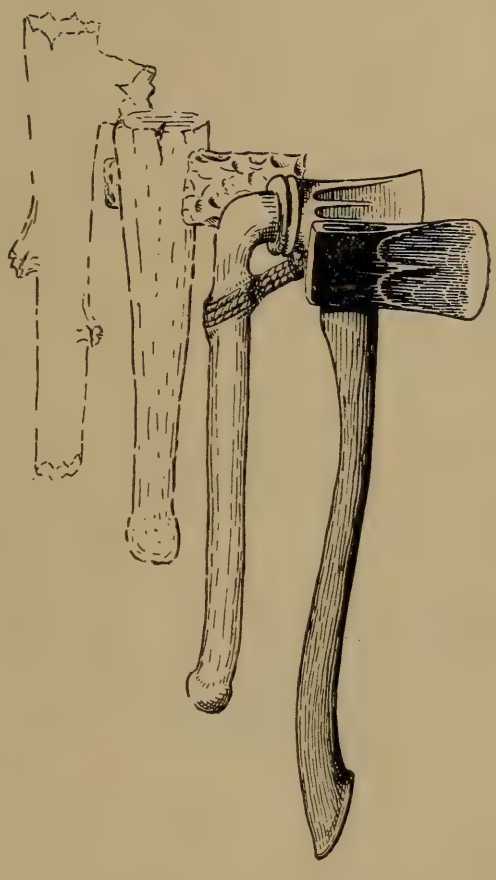
A want differs essentially from a need

in that it expresses a *conscious* perception of lack of adjustment to environment. Self-conscious man alone responds to a want, and inasmuch as self-consciousness is confined to individuals, a community need, in order to be satisfied, must find expression as an individual want.

It is difficult, if not impossible, in the highly specialised condition of self-consciousness now existing, to fully realise a condition of mind in which the individual does not recognise his individuality. But only by assuming such a condition of mind does it seem possible to account for the persistent lack of advance in the animal kingdom and the infinitely slow human progress in its early stages. In the dim ages of the past doubtless many an incipient primeval philosopher pored and puzzled over the riddle of his selfhood, only to give it up as insoluble and go back to chipping flints for a few more thousands of years, by and by to take it up again and again, and always going back to his flint chopping with more reluctance

When finally he was able to say with certainty, I am, I know I am, he was then prepared to say I want, I will. Then another and the greatest epoch in the history of the world had occurred, —it was the birthday of Man. The stone in his hand then became more and other than the claw of the tiger, the tail of the beaver, or the limbs of the bee. It had become a tool, an implement of his conscious will, a means wherewith to satisfy his conscious wants. The tool, from being an end, a mere addition to his limbs, had become a means to other ends, an implement wherewith to hew from Nature things needed to satisfy wants suggested by those which he had already satisfied. Then it was that a sharp point meant a means for piercing; a sharp edge, a means for cutting; not specifically, but generically. He had acquired the knowledge that pointed things pierce, sharp things cut, heavy things crush.

Then slowly came adaptation to particular purposes, resulting in the hammer, the pick, the chisel, and still more slowly the specialisation of each of these into their many forms. The improvement in the tools necessitated greater skill and intelligence for their use; thus skill and general intelligence increased with, and by reason of, the improvement of the tools. In the struggle for existence those survived who economised their vital energy by adopting and adapting the tool and its improvements to more and better uses. Thus, in the tool, man had called to his aid a factor of ever increasing potency, and by his intelligent adaptation of the tool



to new and various uses man had forever become differentiated from his no less skilled animal competitors. Instead of wastefully expending energy in contests of simple endurance, man was enabled economically and summarily to settle disputes by cracking his adversary's skull with a blow of a weapon, and provide at the same time a replenished larder and leisure to enjoy it. Life, which hitherto had been simply an uninterrupted succession of battles and physical encounters, with hardly time to recuperate, had, by economy of his

physical force, become for man easier and more favourable. He had become better adapted to survive. Physical struggle and killing was the order of the day, and he had become killer-in-chief. So well fitted to his environment, indeed, did his killing tools make him, that thenceforward the struggle for supremacy was a losing fight for the rest of the animal kingdom; indeed, it had become but a question of man's requirements or whim which animals should live or die.

As the stress of the struggle against his brute competitors lessened, man's numbers greatly increased, thus constituting man himself a factor. Aggregations of men struggled for supremacy, the stronger and more skillful overcoming and destroying those of less strength and skill. But savage beasts and man's no less savage fellows did not furnish his only enemies, for all the while Nature's brute forces formed a background of destruction still more potent than either, so that when not employing the tool against these animate opponents, man found for it even more active employment as a weapon of defence against Nature. Skill in the use of tools and man's dependence upon them thus ever increased, and as a consequence there came a corresponding increase in their employment and adaptation, and, what is yet more important, there came an ever increasing knowledge of Nature and Nature's laws.

The rivalry of units still continued with scarcely diminished intensity, and as this involved purely personal and individual competition, it constituted a potent factor in fostering individuality and initiative. Individuals who were most skillful with tools, and whose intelligence responded most readily to needs, thus exercised greater and greater economy of effort and acquired most leisure, and so produced conditions most favourable to survival.

The elements, skill, intelligence and motive force, have been gradually changing their relative importance as factors in the outcome of man's employment of tools. Skill was, in the beginning, the most important. A low order of intelligence was more than sufficient for the requirements in man's early stages as a tool user. Individual human strength also was ample for the chipping and hacking necessary to the production and use of the early forms of tools. But time and increasing intelligence brought about new conditions, uses, and avenues for increased skill without greater demands on bodily strength, thus ever encouraging and stimulating skill and intelligence, while human strength remained practically unchanged. As efficiency in the employment of tools is limited by each of the elements involved, so the final result cannot be greater than their sum.

Skill however consummate, combined with intelligence however penetrating, employing tools however perfect, when confined to individual effort, has narrow bounds, owing to the limited motive force resident in individuals. An ultimate limit, therefore, is easy to see. Wants made themselves felt which taxed skill and intelligence less than the available motive force, bringing about the need of a power greater than that of individuals. To meet this need, the obvious, and, in fact, the only available resource, was co-operation of individuals uniting in simultaneous effort. This application of motive force is, at best, cumbersome, lacking the nicety of control required to make its application efficient. The limitation of this crude form of co-operation, therefore, as a controlling factor in progress, was quickly reached, though ages passed without bringing a more perfect substitute. The availability of animals as a substitute for human power is restricted by the same and other limitations, and natural sources of motive power, such as waterfalls, wind power, etc., were largely unavailable owing to their nature and the limited progress of science.

Thus in the ages since the discovery of the tool, conditions changed slowly and imperceptibly, following the natural law of evolution till a time at length arrived when the influence exerted by the tool had exhausted its potency as an active element in human progress and no further change along the same lines

was possible. Stable equilibrium of all the factors and conditions had been reached. Such a condition, it is readily imaginable, might have been prolonged indefinitely or until the present races of mankind had used up their stock of latent energy and died a natural death, as races have done in the past.

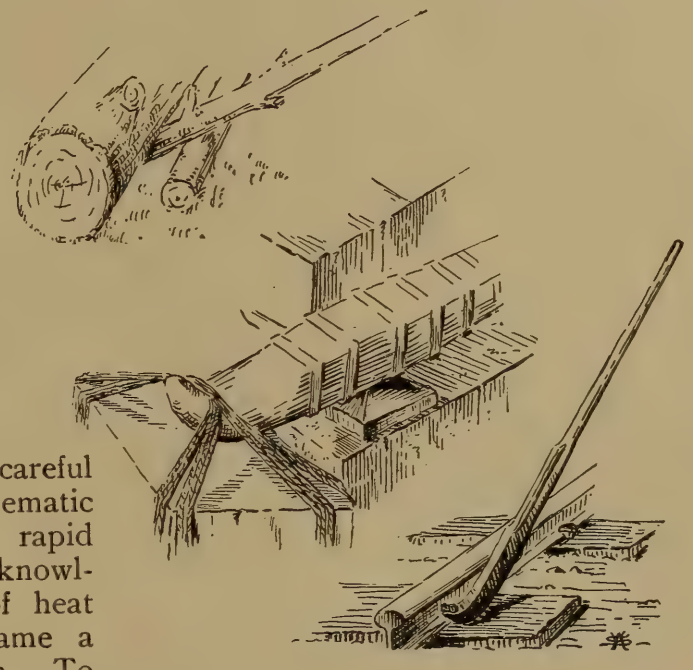
Skill and intelligence had far outstripped the available motive force resident in individuals, and the urgent need of civilised man in his battle with Nature was a powerful motive force, controllable and divisible at will and applicable at any desired point. This need had existed for ages, but till it became a want, appreciated by individuals possessed of knowledge of things adapted to supply it and the skill to arrange them in operative combination, its satisfaction could not be brought about.

Scattered along the centuries, vague, prophetic foreshadowings of the possibilities of harnessing Nature's forces have flitted through speculative minds, only to fade for lack of knowledge of the things necessary to materialise these misty conceptions. The modern method of research,—careful observation of things and systematic experiment,—brought about rapid growth of accurately organised knowledge. The expansive force of heat as a source of power so became a matter of common information. To bring about the long delayed satisfaction of the pressing need of a powerful, controllable, divisible power, all that was now required was that the need should come within the cognisance of a logical mind stored also with the mechanical knowledge necessary to apply devices of kindred conditions to the requirements of the problem. This occurred in the eighteenth century. The result was the invention of the steam-engine.

With this came the satisfaction of the want of a power unlimited as to extent and divisible into units available at any desired point. So the engine as a motor magnificently substituted one of the three components involved in the use of tools,—skill, intelligent control, and motive force.

A motor, however, merely separates and renders available portions of Nature's store of energy. The units so separated remain brute, unintelligent force. So if man was to be relieved of the waste entailed by the other elements of the combination, substitutes for them also must be found to coact with the new factor.

How could the skill and intelligent directive control which had heretofore been employed in the use of the tool be incorporated with the motive force drawn from Nature? The engine, as



at first devised and practically applied, did not meet this want. It was, in fact, but an extension of the tool on an enlarged scale, natural energy being substituted for human motive force. Engines as at first constructed, with an attendant operating the valve mechanism, had not entirely solved the problem. Human intelligent control was still a necessary factor. At this point an event occurred, so simple in appearance as to be almost unnoticeable, but momentous in consequence and far-reaching to the last degree. The valve-controlling cord was connected to a suitable synchronously moving part of the engine. The problem was solved. The want was satisfied. Another crisis

in human affairs had come; another epoch had been reached. By this simple act intelligent man had been freed from harness; the omnipotent genii of Nature's forces were imprisoned, forever the obedient servants of man's will. Man could now stand erect, the master.

THE MACHINE

The modern machine, as a substitute for human intelligence and control, or as a distributor and director of the unintelligent power of the motor, was now possible; its adaptation and its multiplication alone remained as an urgent want. The motor itself gave the key to the solution of the problem. Man, as the motor, could now withdraw from the combination. For his skill and intelligent directive control he had substituted the closed mechanical cycle,—a prearranged series of mechanical movements, each performing its proper function in its appointed sequence, all working to a desired end, and so interlocked as to repeat indefinitely their harmonious action,—the automatic machine, a materialisation of prophetic intelligence. Stable equilibrium of the tool epoch in human progress had been disturbed, and man's evolution must again rearrange itself on a new base. The new era had dawned. The engine, therefore, was not alone a new motor, but was also the prototype of the modern machine. It thus inaugurated in a twofold manner the age of the machine,—the last and most spectacular epoch in man's triumphal progress.

It would seem, then, the tool and the machine are two essentially different instrumentalities; the one is simple, elementary, and basic; the other complex, heterogeneous, and derivative. The one is independent of human reason; the other is its logical product. In brief, the tool is a limited extension of man as an animal, the machine an unlimited extension of man as an intelligence. As they differ in their origin, so they differ in their effects. Whereas the introduction of the tool merely increased man's individual effectiveness in his outward expression of a physical motor, the machine,—by linking man's intelligence with exterior universal energy,—constituted him an intelligent controlling force in Nature.

Coming down to concrete definitions, the tool is an instrumentality of which the law of operation and motor force is resident in the operator. The machine is an instrumentality having a closed cycle of motions of which the law of operation resides within itself.

The new source of motive power having been provided, manipulative skill being amply present, the reasoning faculties having attained a high degree of efficiency in many lines of activity, man's store of knowledge of things and principles acquired by careful observation having become encyclopedic, all the elements were present to bring about the flood of modern machinery which characterised the nineteenth century. As fast as wants presented themselves they were satisfied out of the acquired store of mechanical and scientific knowledge by logical skill producing close cycle or automatic appliances requiring but general supervision.

Automatic machines are simply aggregations of parts so arranged as to permit the forces of Nature, diverted by the motor, to act in directions which effect the desired end. Nature's forces being unreasoning and operating through inert matter, such a machine, of course, acts with absolute precision and unvarying regularity; unlike handicraft, it expresses perfect skill uninfluenced by the human limitations.

It is frequently urged that the introduction of the automatic machine has restricted the employment of the hand worker, and has lessened the individuality and diminished the personal initiative of the operator; that it has had the effect of changing the intelligent, self-respecting hand worker into a mere mechanical adjunct of the machine whose operations he supervises. The automatic machine has, of course, produced a rearrangement of the avenues of labour, with consequent suffering to those who, through lack of intelligence or lack of adaptability, have been unable to adjust themselves to the new conditions. Such is the necessary effect in

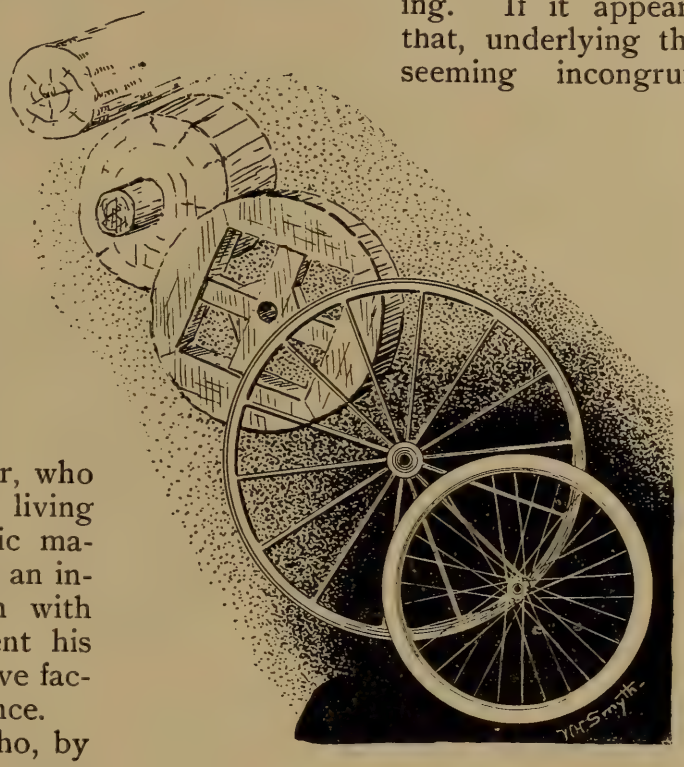
transition periods. The suffering and hardship during the transition from the tool age to the machine age have been insignificant when compared with the enormous increase of comfort and general well-being which have resulted from this change.

That automatic machinery has had the effect of diminishing the individuality and personal initiative is wholly improbable. If the slow moulding of ages, the heredity of generations, and the environment of art, science, and literature can produce a type of men having little or no imagination, individuality, or personal initiative, it would certainly seem that they are of too resisting fibre to be affected, either for good or ill, by a few years' contact with machinery. Such a type, doubtless, performs valuable functions in the economy of the race, by conserving the good of the past and steadying the present. Nature, which has so carefully preserved this type, can be relied upon to still guard and keep it, to act as a balance weight during a few more epochs. To one, however, who has the slightest spark of the living fire of imagination, an automatic machine is a liberal education and an inspiration, the daily association with which must of necessity augment his knowledge, cultivate his perceptive faculties, and stimulate his intelligence.

As in all past times, those who, by reason of natural deficiencies, are unable to adapt themselves to the newer conditions, will inevitably drop by the wayside; but those who possess the necessary flexibility to withstand and accommodate themselves to the change of condition, will flourish and improve, and rise step by step, and enjoy an existence of which the fighting, struggling brute past can offer no analogy or suggestion.

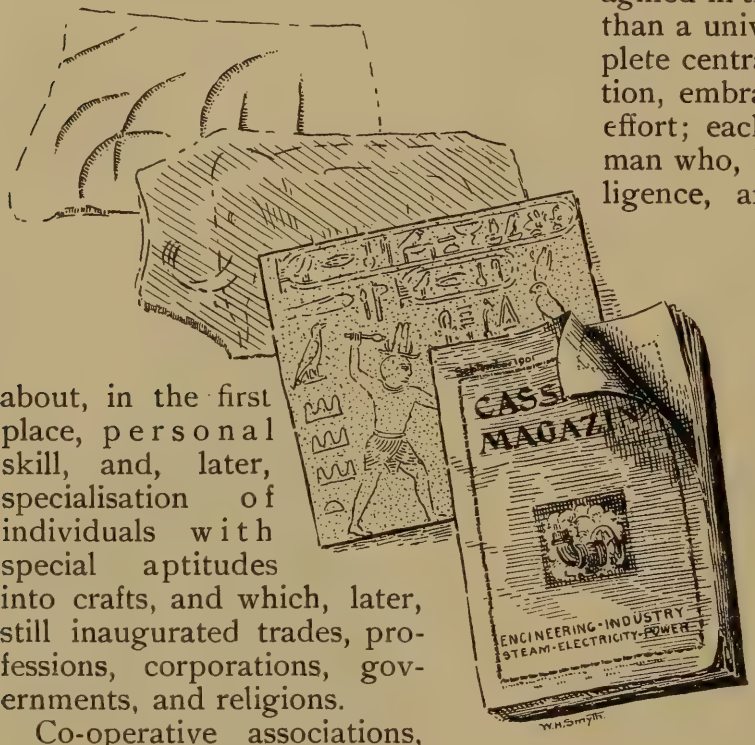
THE MAN

In the evolution of man and of his appliances the reciprocal relation is so intimate that, up to the production of the machine, they cannot logically be separated. The tool, the machine, and the man were each essential to the development of the others. Man's further progress and development, however, involve considerations to which the tool and the machine are merely incidental. As the tool and the machine have been modified and perfected towards an ideal adaptability to their respective purposes, so man by analogous processes has been transformed and perfected towards an ideal adaptation to a purpose. It is not necessary to the present discussion to attempt to determine what the end may be to which man's adaptation is tending. If it appears that, underlying the seeming incongruities, a continuous and consistent plan is discernible, and that this plan involves man's betterment through his own intelligent co-operation, this essay will have accomplished its purpose.



Looking back over man's progress from the present standpoint, certain controlling influences are so clearly discernible as to imply laws in man's development. The first involves economy of human effort; the second, the supreme importance of individuals. Under the control of the first influence evolution has eliminated types and races of men who wastefully squandered their energy in failing to take advantage to

the highest degree of the possibilities of mechanics as expressed in the tool, and the machine, and other labour-saving factors. The pressure of this law and its momentous results are peculiarly in evidence at the present time. Every step in the past has been towards a maximum result with a minimum of outlay. Co-operation in all its forms expresses the operation of the same factors which have always worked towards economy of effort; which brought about, in the first place, personal skill, and, later, specialisation of individuals with special aptitudes into crafts, and which, later, still inaugurated trades, professions, corporations, governments, and religions.



Co-operative associations, unions, and industrial combinations express the same fundamental law of economy involved in the tool and machine. So-called "trusts" may, in a sense, be considered as huge automatic machines whose elemental parts are men and groups of men so arranged as to bring about the greatest possible result with the least expenditure of effort and with a minimum of direct, intelligent control. These combinations stand in the same relation to the division and distribution of the fruits of industry that the automatic machine does to their production. The one expresses the law of economy in the domain of mechanics, the other in the domain of commerce.

The industrial revolution now in progress expresses in high degree the conjoined influence of both factors,—economy and individuality. It is a phase of the readjustment necessitated by the advent of the machine, involving the same character of economies, the same expansion of human mastery and more perfect adaptation. It suggests as possible a condition of socialism without any lessening of the personal incentive which has always been the spur of ambition.

What more ideal socialism can be imagined in the present state of knowledge than a universal combination with complete centralisation of intelligent direction, embracing all branches of human effort; each department directed by a man who, by his specialised skill, intelligence, and knowledge, has proved himself best fitted for such a position, and each member of the community an owner, participant, or stockholder, whose stock and whose position therein exactly represent his realised capability for general good, all unequal, but with equal opportunity, and each individual absolutely free to climb to the highest position in such a "trust" as his capabilities and inclination permit him.

The whole scheme of things in man's evolution seems to indicate the supreme importance of individuals. Notwithstanding an appearance of disregard for individuals, there has always existed, in fact, a constant and unremitting regard for the preservation of certain types of individuals. Of this the acquirement and accentuation of self-consciousness alone furnish marvelous and convincing proof. It would seem that all the forces, both exterior to and inherent in man, have worked and are working towards a type of individuals each so in harmony with Nature's laws as to be practically emancipated from all conditions except such as arise within himself out of his intelligent, logical appreciation of his environment. The whole story of man's uprise has been one of growth from a

condition of servitude towards a condition of liberty,—liberty expressed by a severing of the bonds of instinct and habit and a substitution therefor of intelligent, self-conscious control. Every step has been a gain in personal freedom; every elimination and failure to survive, a sloughing-off of types lacking adaptability to the God-like responsibility of personal liberty.

Ideas are the real factors in human development, and ideas spring only from individuals, never from masses. Every human revolution started from a man, a man with an idea.

There never has been a time when the individual stood for so much as he does at present. There never has been a time when individuality and personal initiative brought such amazing rewards. There never has been a time when the individual could or did exert so much influence as at present. There is no individual to-day so insignificant that if he became the medium of a new or potent idea he would be prevented by uncontrollable conditions from expressing his idea and reaping his just reward. In all the ages up to this, man has been, owing to his limitations of physical force, a plaything of conditions, a slave of his environment. Skill and intelligence were but two of the factors in his progress, bounded and restrained by limitations to their employment. Now, however, with universal energy at the disposal of each individual, this terrestrial sphere scarce puts bounds to his field of influence.

The impetus given to the mechanical phase of human effort by the harnessing of Nature's forces has resulted in so rapid a development of the productive ability that our blessing seems sometimes to threaten the deplorable result of over-production. But over-production is obviously a misnomer for imperfect distribution of the products and inequitable division of the benefits of industry. This must be so, so long as there remain any who are hungry, ragged, or homeless, while willing and able to work.

To find remedies for these discordant conditions, of course, are the immediate problems, the solution of which must be soon forthcoming if man's upward progress is to be unimpeded. Whether the ideas or principles on which "combinations" or so-called "trusts" are based will solve these problems, and whether their application will satisfy these wants, remains to be seen. It can be said, however, that they contain in them the elements through the operation of which such proper distribution and equitable division seems possible. We can hope, and the past gives us reason to believe, that so much in this movement as is for the best interest of all will remain, and that those elements which are harmful will, of their own inherent harmfulness, disappear.

By the growth of intelligence and knowledge, with the aid of his mechanical appliances, man has acquired such dominion over physical nature that the satisfaction of merely physical wants would seem to involve only the question of their desirability or urgency. With unlimited power at his control and with his acquired skill and insight into the principles of things, does it not seem that the satisfaction of the merely physical needs of every human being, to the extent even of the most refined luxuries, is a problem hardly worthy of being the climax to man's career?

There is, however, overshadowing and underlying all the difficulties which confront man, one problem, the solution of which he cannot shirk and which is worthy of his highest efforts and of his most profound consideration,—a task too subtle for legislation, too personal for co-operation, at once a problem and a paradox. By the acquirement of intelligence and self-conscious individuality, each human being has become a potent responsible exterior controlling force, a conscious rational factor in his own growth, evolution and development; subjective and objective in one; himself his own material, himself the artisan,—the highest expression of liberty, master of himself and the servant of all; the problem of problems, the paradox of paradoxes—Man.

THE MEASURING MACHINE IN THE WORKSHOP

By Professor John E. Sweet

THE first machine known to the writer which could be termed a measuring machine was that used by watchmakers, consisting of a double-ended lever, the short end calipering the pivot or shaft, and the long end in the form of a pointer indicating on a dial the size. Within their range these instruments are very serviceable, and, as a means for comparison, quite accurate.

As an instrument of precision the Whitworth millionth measuring machine of sixty-five years ago was the foundation of all our present accurate machine shop dimensions, as were the Whitworth surface plates, the key-note of which was the resting of them on three points, the foundation of flat surfaces.

Whitworth maintained (and for comparing the relative length or size of two pieces, no doubt correctly) that the most delicate sense was that of touch, and in confirmation of this he showed that when a parallel gravity piece was grasped between the measuring points of his machine and allowed to slide down by its own weight the movement of the points to the extent of one-millionth of an inch closer together, or further apart, would appreciably affect the speed at which the piece would fall.

The machine was, so far as the writer can remember, of such size as to be able to measure about three or four inches in length, and it is presumed that his standard was derived from the imperial yard, by making nine or a dozen distance pieces of a uniform length, which, when placed end to end, would equal the yard. Thus having a standard three or four inches in length, three or four pieces of equal length, which, when placed end to end, equaled either one of these, established the standard inch.

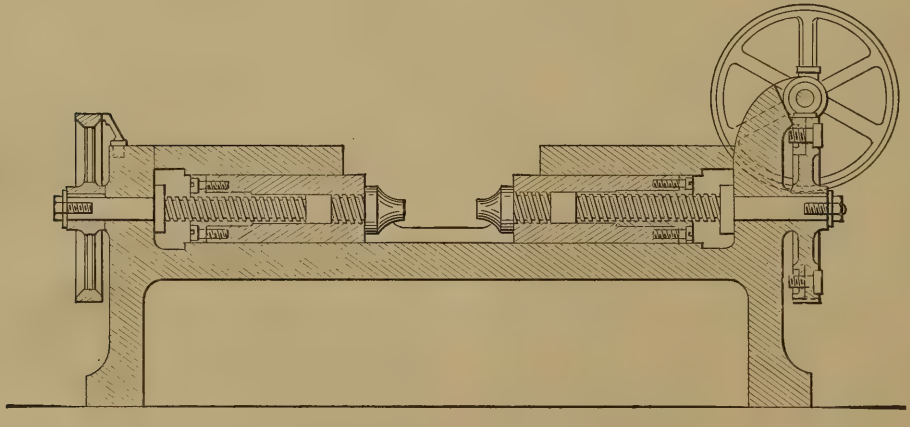
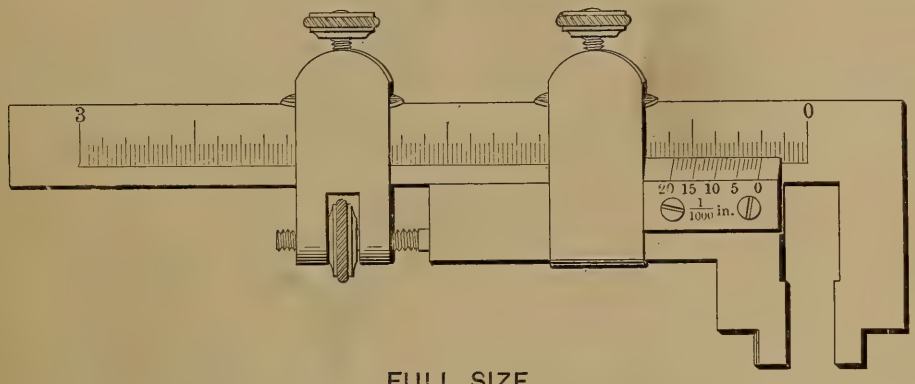


FIG. I.—THE WHITWORTH MILLIONTH MEASURING MACHINE

The accuracy of the Whitworth machine for the sub-division of the inch depends upon the accuracy of the screw, or the screw corrected by a tabulated scale of errors, such as is used by astronomers in connection with their instruments. The plugs and rings made

by Whitworth, accurate probably within the ten-thousandth of an inch, introduced standards in many countries.

While, or perhaps before, Whitworth began to furnish the workshops of the world with standard plugs and rings,



FULL SIZE

FIG. 2.—A BROWN & SHARPE POCKET VERNIER CALIPER

Samuel Darling, of Bangor, Maine, U. S. A., did as great work in the way of improving machine shop measurements by the introducing of standard scales of great accuracy. This work dates back as far as 1850, and so complete and perfect were his devices that it is doubtful if, in a commercial way, it has ever been equaled, certainly never exceeded, for even now the Darling, Brown & Sharpe scales are the standard of excellence in that line. Not many years later their vernier caliper was put upon the market, and this, in one sense, became a measuring machine for machinists' use.

About 1867 Brown & Sharpe, in the United States, put upon the market a French invention, the micrometer of Palmer,—a sheet metal gauge,—which, though perhaps not the first made, was found to be in practical shape, and is the model of all the micrometers now found in practical use. So far as known to the writer, the first machine made in the United States that aimed to meet larger dimensions and accuracy below the one-thousandth of an inch was the measuring machine built at Cornell University in 1873 and 1874 by John S. Waterman, a student, from a design by the writer, which possessed some features that, so far as known, were original. First, as will be seen from the illustration on the opposite page, the frame rests upon three feet, an arrangement recently adopted by the Pratt & Whitney Company, of Hartford, Conn. The movable foot stock possesses the merit that if a screw which will sub-divide a single inch perfectly can be secured, all distances up to the length of the machine can be measured with equal accuracy; and, further, the machine is set anew for every measurement to be made, thus entirely eliminating errors due to wear or difference in temperature, except the wear in the screw itself. The errors due to wear in the screw and nut are reduced far below that in any other machine made before or since by making the screw and nut of equal length, and the thread of such

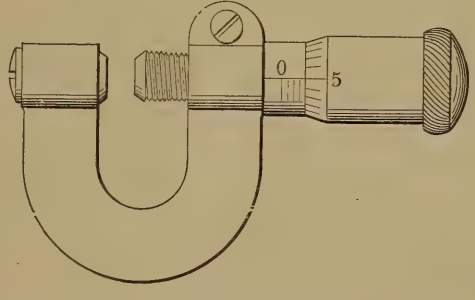


FIG. 3.—A BROWN & SHARPE MICROMETER CALIPER, FULL SIZE, FOR MEASURING ALL SIZES LESS THAN 0.3 INCH BY THOUSANDTHS OF AN INCH

a form that wear can be taken up and end-shake as well as side-shake eliminated.* This form of construction ad-

*As evidence that proves equal length wearing surfaces to be more than a theoretical notion, the writer begs to present the following facts from his

mits of testing the screw for uniformity by simply using two distance pieces of different length. If, by setting the foot stock in different positions, the distance pieces show the same difference in length throughout the entire range of the screw, then the pitch must be uniform, although it may not be standard.

The measuring points of the screw and foot centre are of hardened steel, as, no doubt, was the case in the Whitworth machine, as are also all of the distance pieces or standards which are 5-16-inch steel wire drilled at the ends, and hardened steel surfaces set in, exactly as patented five years later by Mr. Pratt. These standards, varying by inches from 1 to 12 inches, were jacketed in the following manner:—Wood cylinders, about ¾ inch in diameter and a quarter of an inch shorter than the distance pieces, had holes bored through their centres larger than the wire from which the standards were made, and the wires were secured at the ends by wood cones driven and glued in. These wood cylinders were ground to perfect truth, and served as guides from which the ends were lapped to length.

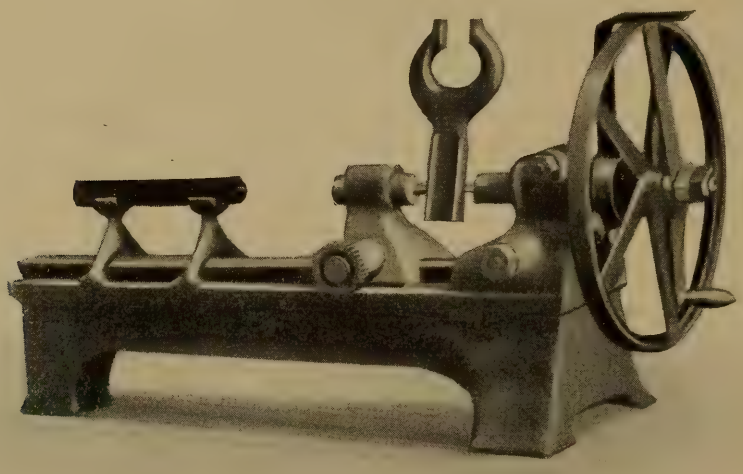


FIG. 4.—THE CORNELL MEASURING MACHINE AND FIXED CALIPER GAUGE

The method adopted for determining the standard lengths was as follows:—A Whitworth 6 inch standard was obtained and duplicated, and the two were combined to establish the 12 inches. It was assumed that the screw which was a reproduction from a Whitworth standard was probably true within five one-thousandths, so the 11-inch standard was ground to 11 inches and 5-1000; the 10 inch standard was made 110 inches and 10-1000, and so on, adding five one-thousandths to each piece, so that, had the screw been perfect, the 7-inch standard should have been, when compared to the 6-inch, twenty-five one-thousandths too long. This was found not to be the case, proving that the screw was not standard, and to correct this a simple scheme was resorted to, which the writer supposed

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own experience:—Thirty years ago a milling machine was built in which both the vertical and horizontal slides and guides had wearing surfaces which were of equal length. This machine was illustrated in *Engineering*, of London, in April, 1871. The machine was used continuously for twenty-eight years, much of the time twenty-two hours a day, and neither of the slides ever had, or needed, the gibs taken up.

In 1872 the first Straight-Line engine was built. The plan of the engine was of such a nature as to admit of crosshead and guides of equal length. When the engine was worn out it was found that both were as straight as when made.

Ten years ago it became necessary to have a lathe that would cut threads on piston rods and in crossheads and maintain a constant pitch, which no ordinary lathe would do for any length of time. A sleeve adjustable along a rod, so as to be set anywhere along the lathe, was threaded for 8 inches in length and a nut which could be secured to the slide rest was threaded for 8 inches also. This screw and nut have maintained a constant pitch, although used for cutting threads of all lengths, and will until worn out.

was original, but which he was afterwards informed by Mr. Charles T. Porter, was the same principle used in a micrometer he saw in France in 1867, correct position, and the index did not stand at zero, instead of repeated trials in setting the foot stock to get it right, the index could be turned back and

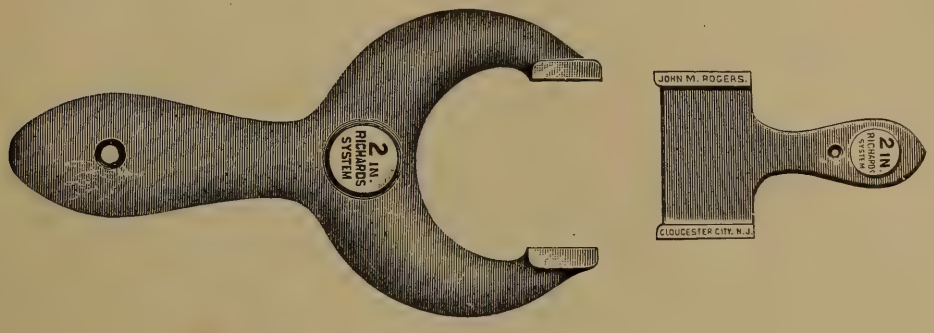


FIG. 5.—RICHARDS FIXED CALIPER GAUGES

and which probably was the Palmer instrument copied by Brown & Sharpe. It was to simply cut the edge of the index at an angle, so that when the screw appeared to be rotated full sixteen revolutions, it was not to quite that extent. By a continued reduction of these standards, and in like manner the shorter ones, the whole group was forth to secure the proper reading. The index was graduated into sixteenths to correspond to the pitch of the screw, and threaded onto the boss of the headstock with the same pitch as the measuring screw, so that turning it backward or forward did not misplace the sixteenth-inch readings.

The crank-handle, as will be seen,

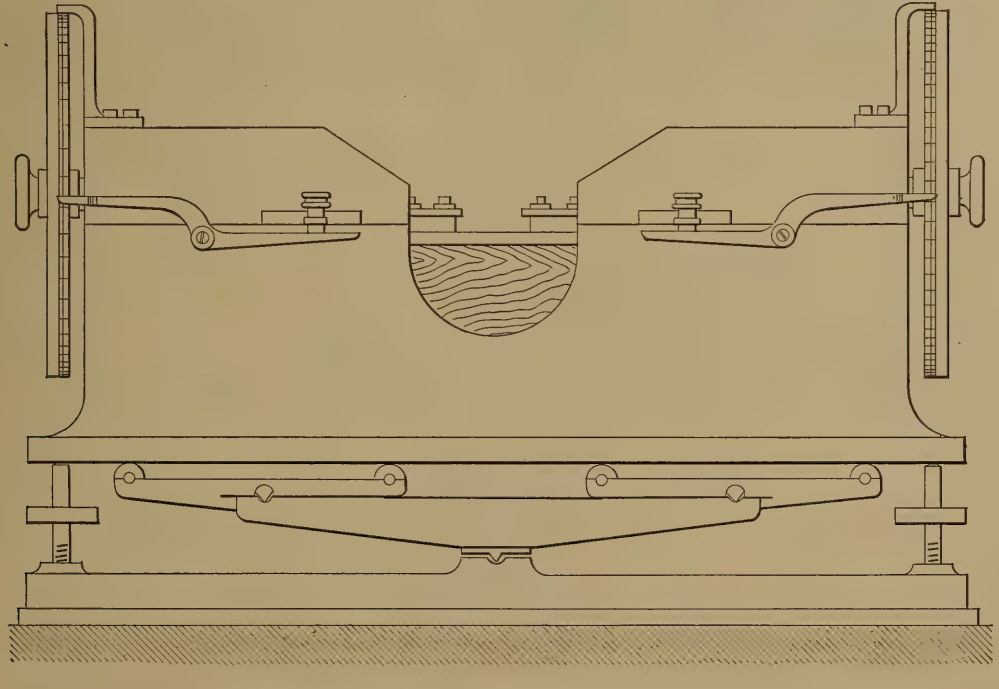


FIG. 6.—THE ORIGINAL RICHARDS MACHINE

brought down to practical accuracy. Another feature about the index was making it adjustable, so that when the foot stock was set in approximately the was not rigidly fixed to the index wheel, but to a cross-bar which drove the wheel by friction, the idea being not only to prevent undue strain on the machine,

but so to adjust the pressure against the piece being measured as to eliminate the personal factor. The Brown & Sharpe Manufacturing Company, of Providence, R. I., and the L. S. Starrett Company, of Athol, Mass., U. S. A., in their recent spring ratchet attachment to their micrometers have accomplished the same end, and what

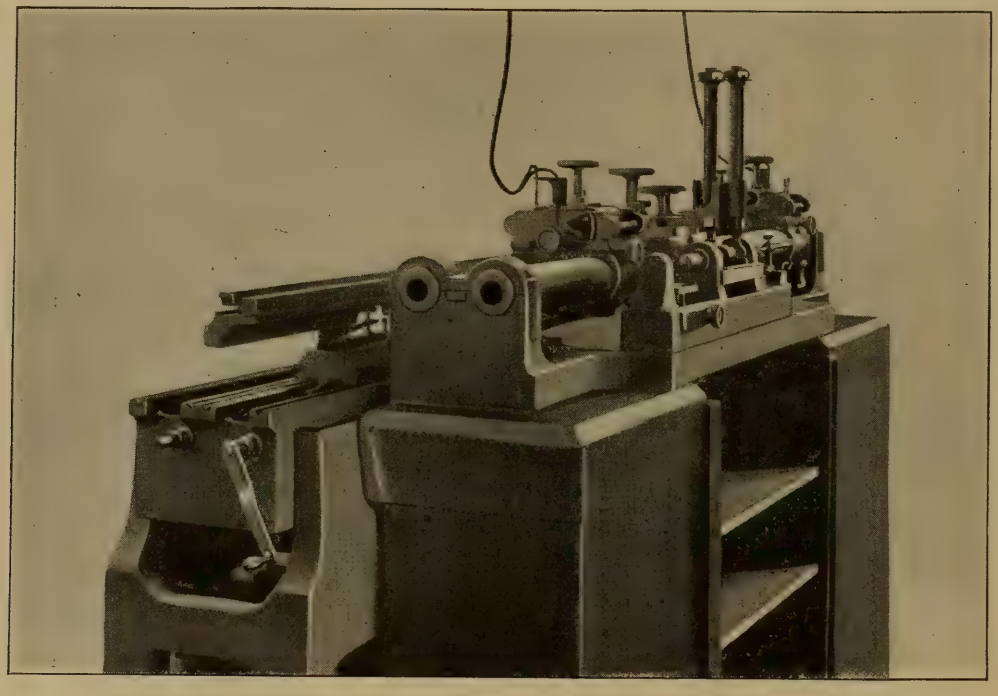


FIG. 7.—THE ROGERS-BOND UNIVERSAL COMPARATOR FOR THE COMPARISON AND INVESTIGATION OF STANDARDS OF LENGTH AND MEASUREMENT OF GAUGES. OPERATED BY THE PRATT & WHITNEY CO., HARTFORD, CONN., U S. A.

apparently is an identical device was patented in 1889 by Mr. John Richards.

The use of the plug and ring gauges furnished by Whitworth were found inconvenient and too expensive to be worn out by machine-shop use, so that "snap" or fixed caliper gauges, somewhat resembling the one shown in the Cornell measuring machine, were made from forged or sheet steel by the owners of the Whitworth gauges, and, in a limited way, for outside parties. These gauges, however, differed in this, that the measuring points were very small, scarcely more than points.

In 1864 the pattern for the gauge shown in the Cornell machine was made and sent to Great Britain for steel castings, which at that time were first beginning to be made in Birmingham, though before that in Scotland, but not in the United States. The steel castings not proving good, nothing was done with the gauges until the Cornell machine was completed, when castings were procured from white iron, and the gauges were made with surfaces one-half the diameter in width. The writer is under the impression that white iron is the best material, and the wide faces are surely more enduring than the narrow ones. Narrow parallel surfaces have since been used exclusively; surfaces one-half the diameter in width are far better, though expensive to make.

From 1860 until 1874 or 1875 Mr. John Richards, now of San Francisco, was working at the problem of establishing the manufacture of fixed caliper gauges for the market, and his work, though later carried on by his son, George Richards, now of Brussels; by his son-in-law, Mr. Taylor, and now by John M. Rogers, of Gloucester City, N. J., U. S. A., can fairly be said to be the pioneer work and Mr. Richards to be entitled to the honour as the founder of the industry in the United States.

The Richards machine, Fig. 6, reading to ten-thousandths, in general resembles the Whitworth machine and in the use of two screws, the screws moving slides and in line with the measuring points.

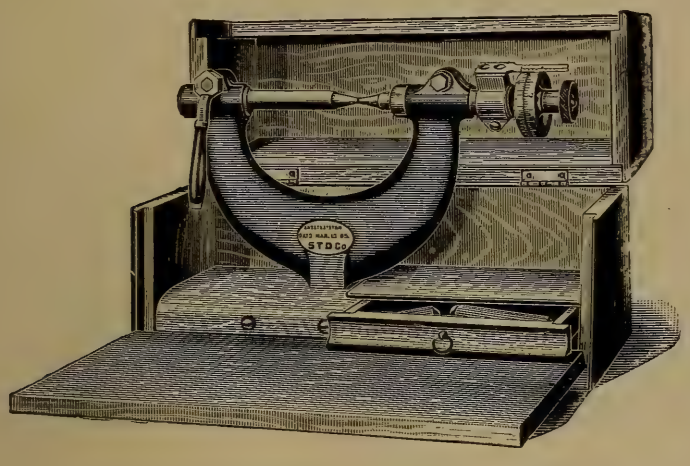


FIG. 8.—FOUR-INCH MACHINE MADE BY THE SYRACUSE TWIST DRILL CO., SYRACUSE, NEW YORK

This machine measures up to 6 inches, and, like the Whitworth machine, has 10 and 8 pitch screws. As the wheels and screws have no end travel, the movable index hands, shown in Fig. 6, were introduced to correct the errors in the screws. They were devised by Mr. George Richards, as were also the equalising levers to overcome the bending of the frames, which though apparently very rigid, would spring to a serious extent if rested in different places.

The machinery devised and the method of grinding the gauges were novel, and were arrived at after a great deal of experimenting. To rapidly machine and grind the narrow surfaces, and to grind the parallel faces of the outside caliper, developed difficulties not contemplated or seeming possible, and to overcome these difficulties, and in a way that would be within reasonable cost, was just what made the business a success. Added to this was good judgment as to what limits of error it was necessary to maintain to meet the practical demands. Absolutely accurate caliper gauges cannot be made; they are not needed, and would cost too much if they could be made. Caliper gauges are made for workshop use and not for making standard gauges, and while any good machinist can, of two cylinders, one of which is one ten-thousandth of an inch larger than the other, readily select the larger, in actual work when one piece is to be a running fit, or a forced fit in a hole, he cannot tell which is which, and in none but the most delicate work is any such accuracy of any advantage. Whitworth being satisfied by an accuracy of one ten-thousandth for the plugs and rings, and Richards with an accuracy proportional to the necessity of the large majority of American machine shops, kept the cost down, and this was what rendered it possible to introduce caliper gauges into general use and prepared the shops for doing better work, creating, as it did, a demand for the more perfect gauges.

Some time in the early eighties the Pratt & Whitney Company, of Hartford, Conn., U. S. A., in undertaking to furnish standard test gauges for screw

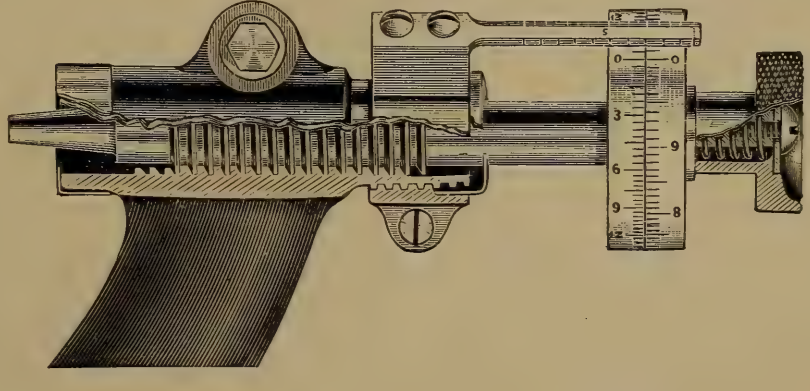
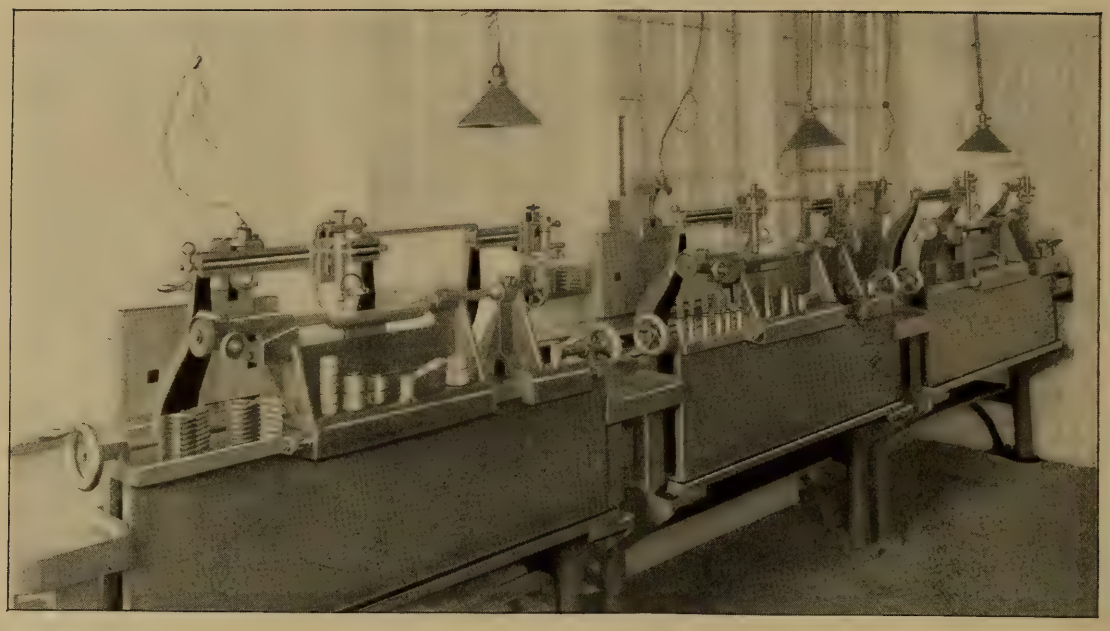


FIG. 9.—THE INTERNAL STRUCTURE OF THE HEAD

threads, found, by comparison, that no two parties who claimed to have established the standard inch agreed exactly, and so they determined to do it for themselves, and expended far more time and money than had ever before been



FIF. 10.—MEASURING MACHINES AT THE BROWN & SHARPE MFG. CO 'S WORKS AT PROVIDENCE, R. I., U. S. A.

devoted to the subject. The Rogers-Bond comparator, Fig. 7, was the result. It depends for its accuracy upon the line graduations on a bar of tempered steel. This has the merit of never changing its length by wear, which cannot be said of the standard distance pieces, and can never vary except by variation in the length of the tempered steel bar, which is likely to be less and less as time goes on. The reading is done by a microscope.*

Owing to the change going on in hardened steel, gauges can be made better than they will remain, and better than needed, except in special cases, and better than the men who use them can work, or generally are required to work. In 1880 the writer had made a half-dozen 4-inch measuring machines, Fig. 8, such as are now furnished by the Syracuse Twist Drill Compny, of Syracuse, New York. These embodied the following features, taken from the Cornell machine:—Screw and nut of equal length; ratchet thread; tail point adjusted to distance pieces for different inches; adjustable index and correction for the error in the screw; and, in addition, the machine was made a bench as well as a hand machine, which could be carried to the work. Aside from the sheet-metal micrometer of Brown & Sharpe, this was the first hand machine, known to the writer, that would measure machine-shop sizes, at least above 1 inch. Machines above 1 inch have since been made by various makers, but none with anything but *V*-thread screws, with short nuts, which cannot but wear smaller in one part than at another, and cannot so wear without impairing their accuracy.

All these machines possess an advantage in common machine shop use over and above standard caliper gauges, or plugs and rings, in this, that in working to size, the machine indicates to the workman just how much too large the piece is; and, too, if an allowance is to be made for a forced fit or a loose fit, he has at hand a true measure to work by. With solid standard gauges to set the machine by, comparatively slight wear comes on the standards.

The Brown & Sharpe machine used for gauge making, Fig. 10, is on the lines of the Pratt & Whitney machine, in that a graduated bar is depended upon for maintaining the standard and with machines designed for such work, to one who knows how easily very rigid

* An extended account has been given in a work by George M. Bond, published by the Pratt & Whitney Company, of the means taken to establish the standard, as well as a description of what had previously been done by others.

machines can be sprung out of shape, both the above machines appear as if nothing but the most delicate care in manipulation would insure satisfaction; but the results appear satisfactory.

From this it will be seen that the Whitworth standards were from about one three-thousandth to one two-thousandth too short, and that the Pratt & Whitney and Brown & Sharpe measure-

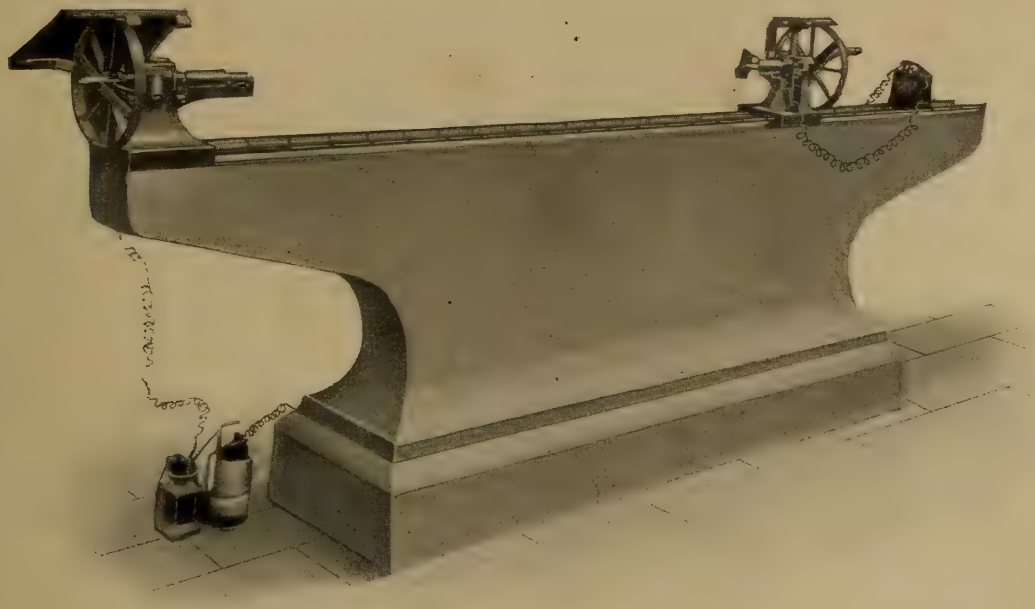


FIG. 11.—MEASURING MACHINE BUILT BY MESSRS. T. COOK & SONS, BUCKINGHAM WORKS, YORK, ENGLAND

In 1893 Mr. John Richards presented the writer with the original Whitworth standards that were used in the adjustment of the Richards machine. These standards were measured in both the Pratt & Whitney and the Brown & Sharpe machines, with the result shown in the annexed table:—

Whitworth	Brown & Sharpe Reading	Brown & Sharpe Error	Pratt & Whitney Reading	Pratt & Whitney Error	Discrepancy Between Readings
1"	.99967	.00033	.99965	.00035	.00002
2"	1.99957	.00043	1.99954	.00046	.00003
3"	2.99959	.00041	2.99958	.00042	.00001
4"	3.99954	.00046	3.99955	.00045	.00001
6"	5.99961	.00039	5.99966	.00034	.00005

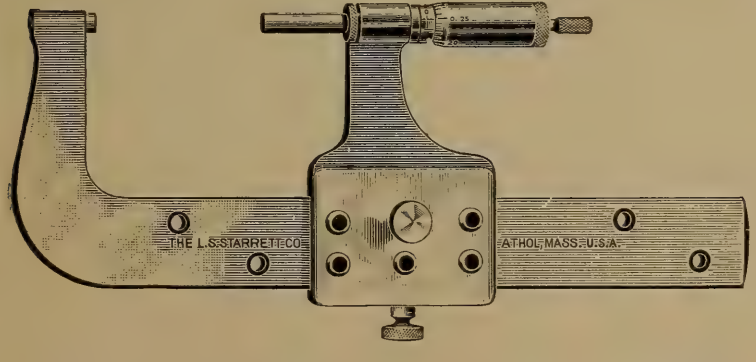


FIG. 12.—MACHINE MADE BY THE L. S. STARRET CO., ATHOL, MASS., U. S. A.

ments varied from each other to the extent of one twenty-thousandths to one one-hundred-thousandths.

It is safe to assume that the Whitworth standards had been used for thousands of measurements and were thereby worn to some extent; and it is possible, too, that either they or the imperial yard had changed in the forty or fifty years between the times the Whitworth and the other comparisons were made.

Various measuring devices have been proposed and made with a movable foot stock in which a series of notches are made for a catch, or in which holes are drilled for a pin, the holes being different distances apart to locate the foot stock measuring point, in place of using distance pieces to locate for the different inches. The trouble to be anticipated from such a system is that

due to dirt getting into the holes or notches. A little dust does not amount to much, but neither is one ten-thousandth of an inch much.

The most important machine of this class known to the writer is one seen at

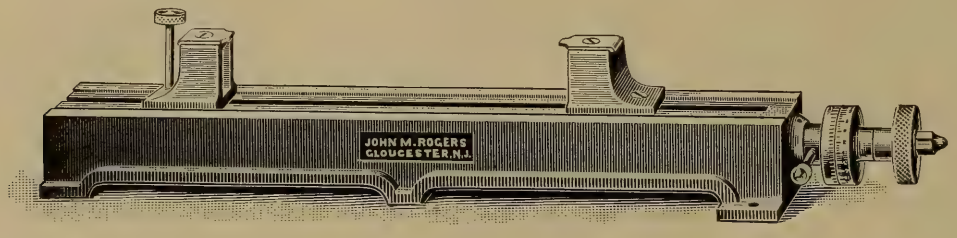


FIG. 13.—STANDARD BENCH MEASURING MACHINE MADE BY THE JOHN M. ROGERS BOAT, GAUGE AND DRILL WORKS, GLOUCESTER CITY, N. J., U. S. A.

the works of the Van de Kerchove Company, at Ghent, Belgium, built, after their designs, by Messrs. T. Cook & Sons, York, England, Fig. 11. It will measure all lengths between 0 and 2.5 metres, or between 0 and about 8 feet, and is guaranteed as exact to $\frac{1}{500}$ millimetre. The foot stock steps by 4

by physicists. To the writer it always seemed that the delicacy of the indicator depended too much on the alertness or mental sluggishness of the operator.

For long distances in machine shop work it is, no doubt, far outside the ability of the workman to keep a piece so near one temperature that the change from temperature variation alone will not exceed the errors in measurement. Of all machines where notches or holes are used, Starrett's machine, Fig. 12, in which a different hole is used for each position, promises the best. Hardened

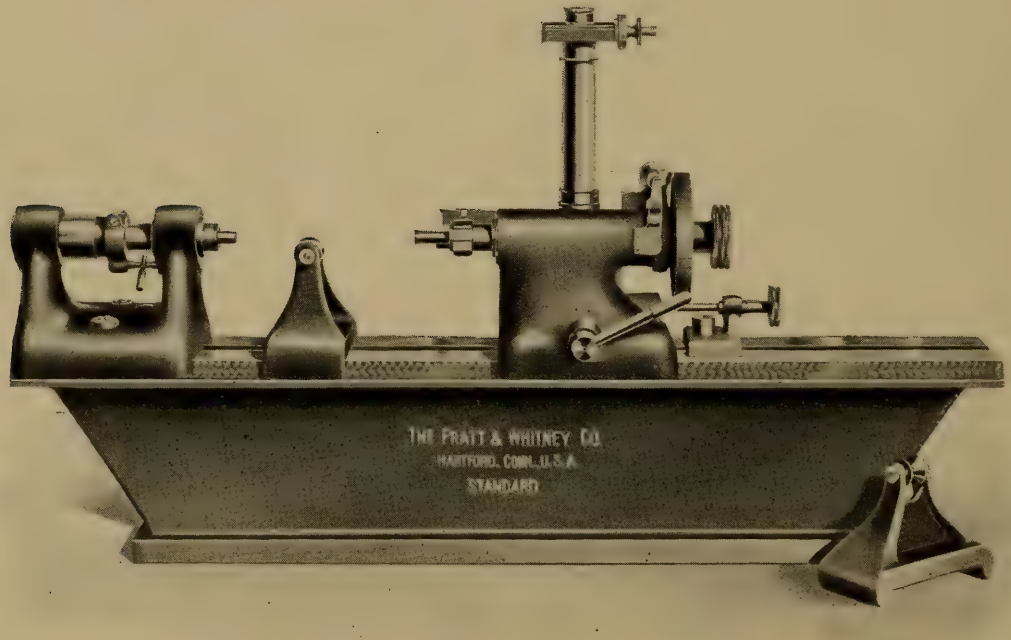


FIG. 14.—MEASURING MACHINE MADE BY THE PRATT & WHITNEY CO., HARTFORD, CONN., U. S. A.

inches and also by decimeters, the screw sub-dividing those distances. One special feature not elsewhere noticed is the electric contact indicator so much used

steel bushes with a hardened steel taper pin leave only dust or dirt in the hole for error; if once true, wear will have little effect towards upsetting it.

Within the last twenty years several bench or tool-room machines have been brought out, of which the Richards machine was one of the first, now furnished by the John M. Rogers Boat, Gauge and Drill Works, of Gloucester City, New Jersey, U. S. A. This, Fig. 13, is provided with an adjustable index, which, with a table of errors, renders it possible to compensate for errors in the screw. This, with screws and slides below the measuring points, would seem to be wrong in principle, and slides such as these will wear some time and become loose in some places and tight in others. The plan used in the Pratt & Whitney machines, Fig. 14, to indicate pressure on the points is a modification of the Whitworth, and probably the best yet devised. A small standard plug is placed horizontally between stops and held by a spring grasping one end. When the measuring points are brought together or against the piece to be measured, the standard plug will be slightly relieved and fall into a vertical position, so that just the difference in the pressure between what it takes to hold it from tipping down and falling is a measure of the pressure.

The machine built by J. E. Reinecker, of Chemnitz, Germany, Fig. 16, differs from others in the use of a column of water or other fluid in a glass tube which indicates the pressure like a thermometer. The footstock measuring point is set in a sliding plunger, and this is backed by a diaphragm on the face of a large chamber. Pressure applied to the diaphragm forces the water up the column, and when this water is forced to the same height the pressure against the points will be the same. In one respect this plan possesses an advantage over the others ; if the pressure should be put on too carelessly and go too high, it may be let down; whereas, in the other cases, if the operator is careless, he must start in anew. A similar plan was outlined by Professor John L. Morris when the Cornell machine was built, but the suggestion carried with it the use of mercury, and owing to its great change in bulk by change in temperature it seemed to promise more errors than it would cor-

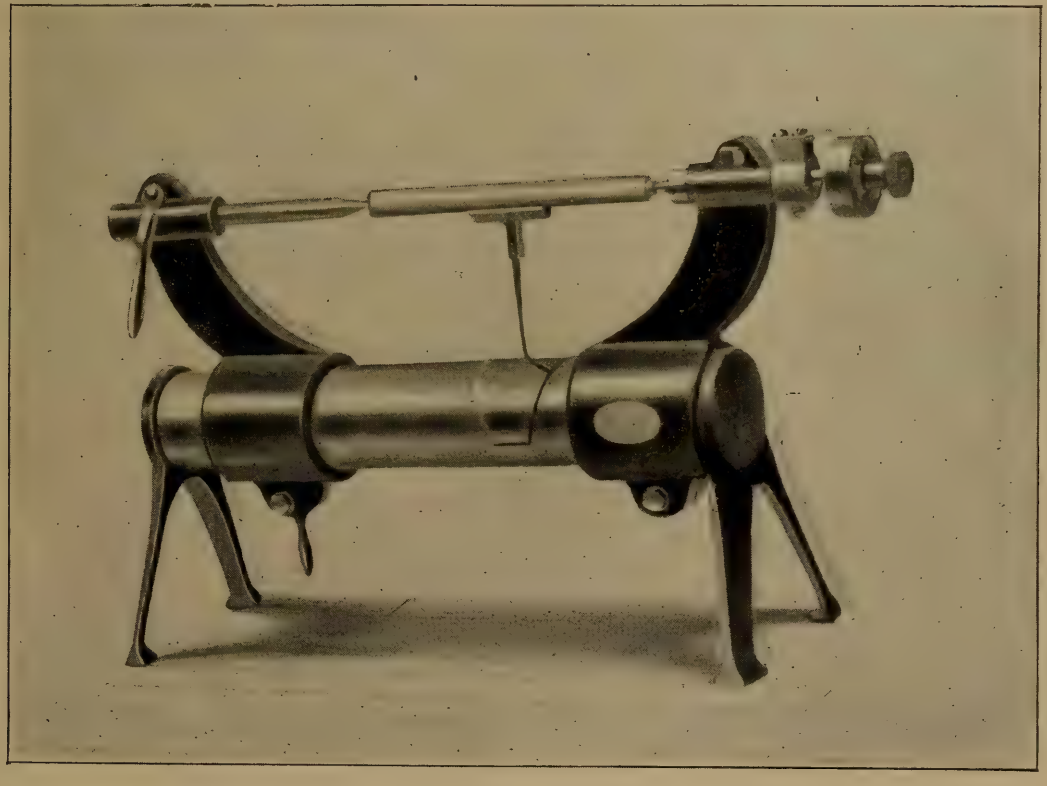


FIG. 15.—MACHINE MADE BY THE SYRACUSE TWIST DRILL CO., SYRACUSE, N. Y., U. S. A.

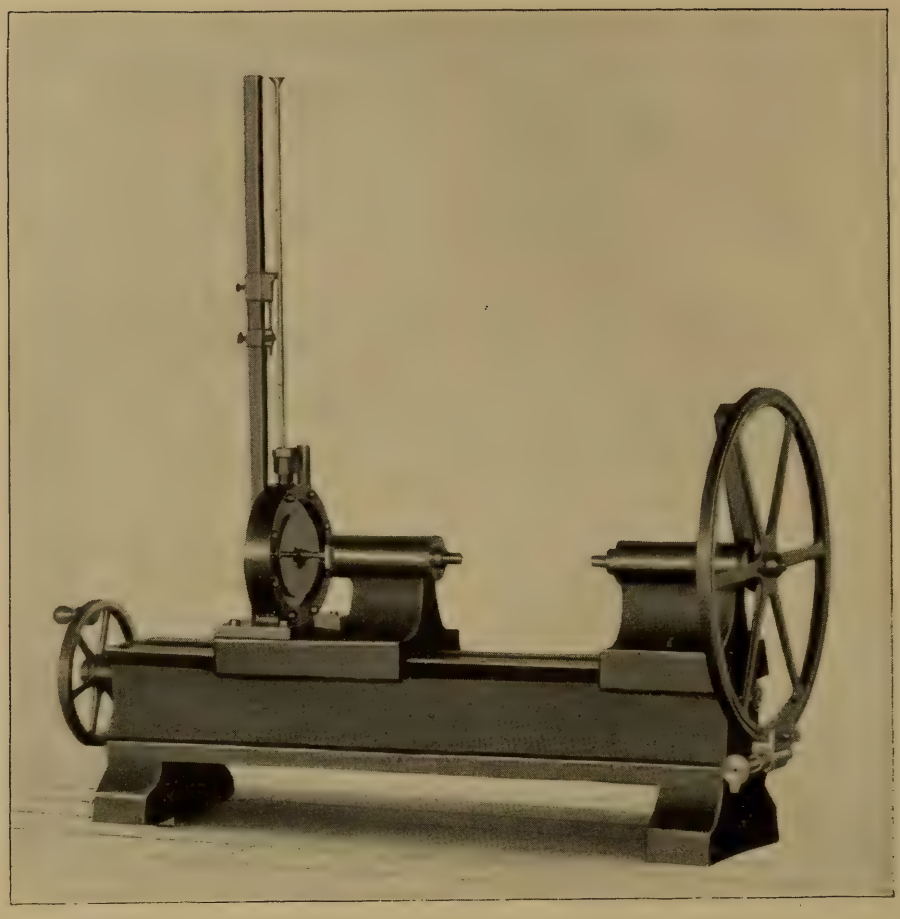


FIG. 16.—MEASURING MACHINE WITH PRESSURE REGISTER, MADE BY J. E. REINECKER, CHEMNITZ-GABLENZ, GERMANY.

rect, and, therefore, was not further thought about. The use of water in the place of mercury may make just the difference between practical success and probable failure.

The Rogers machine appears to rest on a support at each end and one in the middle, as bad a plan as can well be devised. The Pratt & Whitney machine rests on the whole length, which would be equally bad had they not, as previously stated, added as has Reinecker, three points of support. The Syracuse Twist Drill Company's machine appears to rest on four legs. One pair of these is pivoted to the bed, so that the machine is, in effect, on three points.

These different tool-room machines, and the hand machines of which the sheet-metal gauge was the embryo, and those of Richards, Pratt & Whitney, and the Syracuse Twist Drill Company, full grown, are fast making for themselves a field of usefulness.

MACHINE TOOLS AT THE GLASGOW EXHIBITION

By Joseph Horner

FROM the engineer's point of view, the Glasgow Exhibition is well worth a visit, especially by all who are interested in machine tools, stationary steam-engines, pumps, the applications of compressed air to small tools, heavy steel manufacture, naval design, and electrical work. Those who would be greatly disappointed in a visit are men who would come expecting to find hoisting machinery, hydraulic machines, locomotives, tubes, textile machinery, steam boilers, special tools for shipyard use, large gas-engines, motor cars,—a list, too, which does not by any means exhaust the departments of industry which figure to so slight an extent at Glasgow as to be, for all practical purposes, non-representative of British practice.

Those firms who have exhibits will probably score, for there is no doubt about the Exhibition being a success and substantial orders being booked. Certainly, too, the firms who have heavy goods deserve much praise for their enterprise. Here is a big machinery hall of five bays, and not a bit of hoisting tackle anywhere with which to haul about heavy machine tools,—some of which weigh six tons or more, engines, and massive steel armour plates,—or to erect them in place. Everything has had to be moved slowly with rollesr, and poles, and by an expenditure of vast human labour. Yet though the design of the building would not admit of the use of heavy travelling cranes, cheap, portable, tall timber gantries, to span the spaces allotted for exhibits,

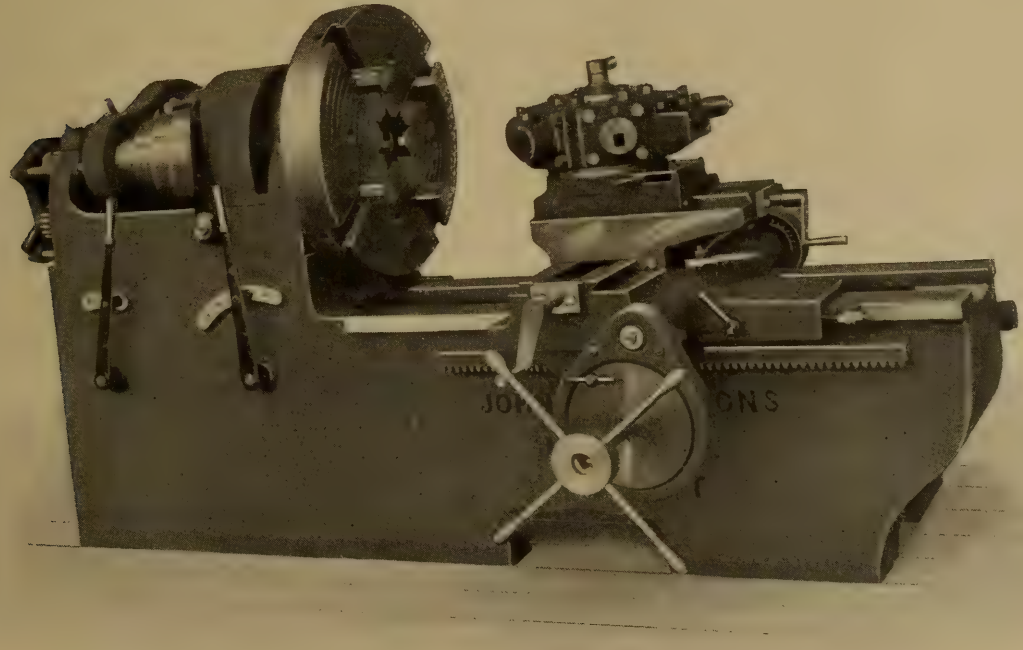


FIG. I.—SURFACING AND BORING LATHE MADE BY MESSRS. JOHN LANG & SONS, JOHNSTONE, SCOTLAND

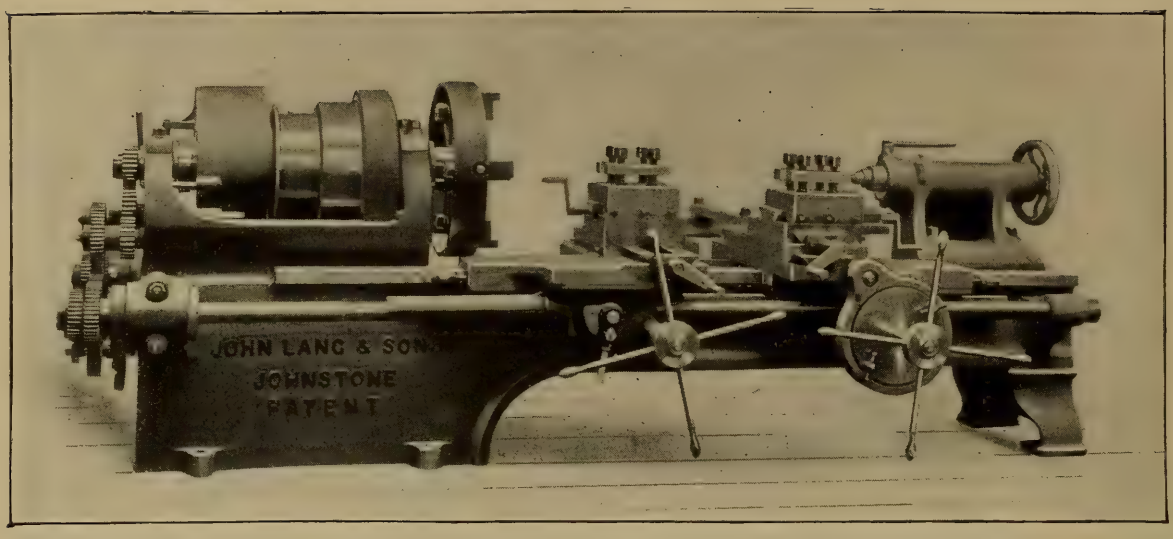


FIG. 2.—SHELL TURNING LATHE MADE BY MESSRS. JOHN LANG & SONS, JOHNSTONE

might easily have been provided to run on temporary rails on the floor, and a charge made for their use.

This is not the place to dwell on the popular side of the Exhibition, but even utilitarian engineers will enjoy the rich collection of pictures, second to none which has yet been brought together in any exhibition in Great Britain, and the extensive and priceless relics of the romantic Scottish history, and the interesting colonial and foreign exhibits. In this article it is proposed to deal only with the machine tools as a whole.

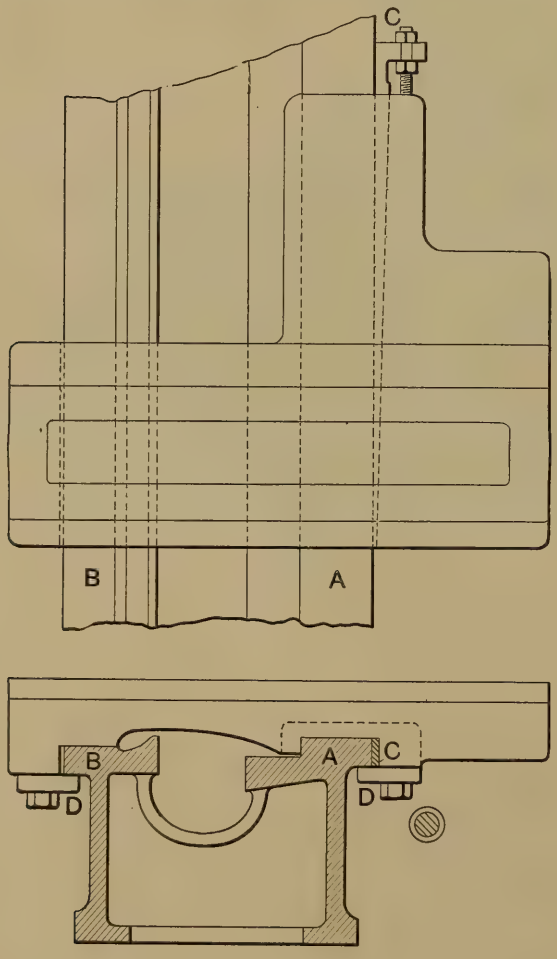


FIG. 3.—MESSRS. LANG & SONS' LATHE BED

In Glasgow one must, by courtesy, concede the first notice to some of the tools made in bonnie Scotland. Much interest centres in the stand of Messrs. John Lang & Sons, of Johnstone. This firm is a live one, familiar with the economies demanded by modern practice. One result is that they have narrowed their range of manufacture, and now make scarcely anything besides lathes and one excellently modelled type of boring machine. They work on large stocks, putting in hand as many as fifty lathes at once in each of the smaller sizes, and are thus able to reduce the cost of production and to deliver immediately to order from the storerooms.

The lathes of this firm have been remodelled in several important respects on the old patterns. Latterly a new type of bed has been introduced which lessens the tendency to twist and spring that exists in the ordinary design, and which provides a better bearing longitudinally for the saddle, as shown in Fig. 3 on this page. The saddle fits closely by vertical edges on the front shear *A*, merely sliding on the face on

the hinder one *B*. By making it fit thus on the front shear only, a much greater ratio is obtained between the length and the width than is possible in the common type, the proportion being six or eight to one instead of about two to one, while the power for moving the saddle is concentrated more approximately in the same plane as the lead screw than is the case when the saddle makes a close fit with the back as well as with the front shear. It is tightened by a long wedge *C* in front, adjusted with a screw instead of by the usual setting-up screws, and the saddle can-

Though the wedge in the saddle is tightened with a screw and nuts from the thick end, as in Fig. 3, in the upper slides where this device would be in the way, the heads of the adjusting screws are sunk in flush, and tightening is effected by slackening the screw at the small end, and setting up that at the thick end.

A new turret lathe by this firm, Fig. 1, is an adaptation of their standard 30-inch swing surfacing and boring lathes. The head is of that type which has the Lang handle feed motion the range of which has been extended, giv-

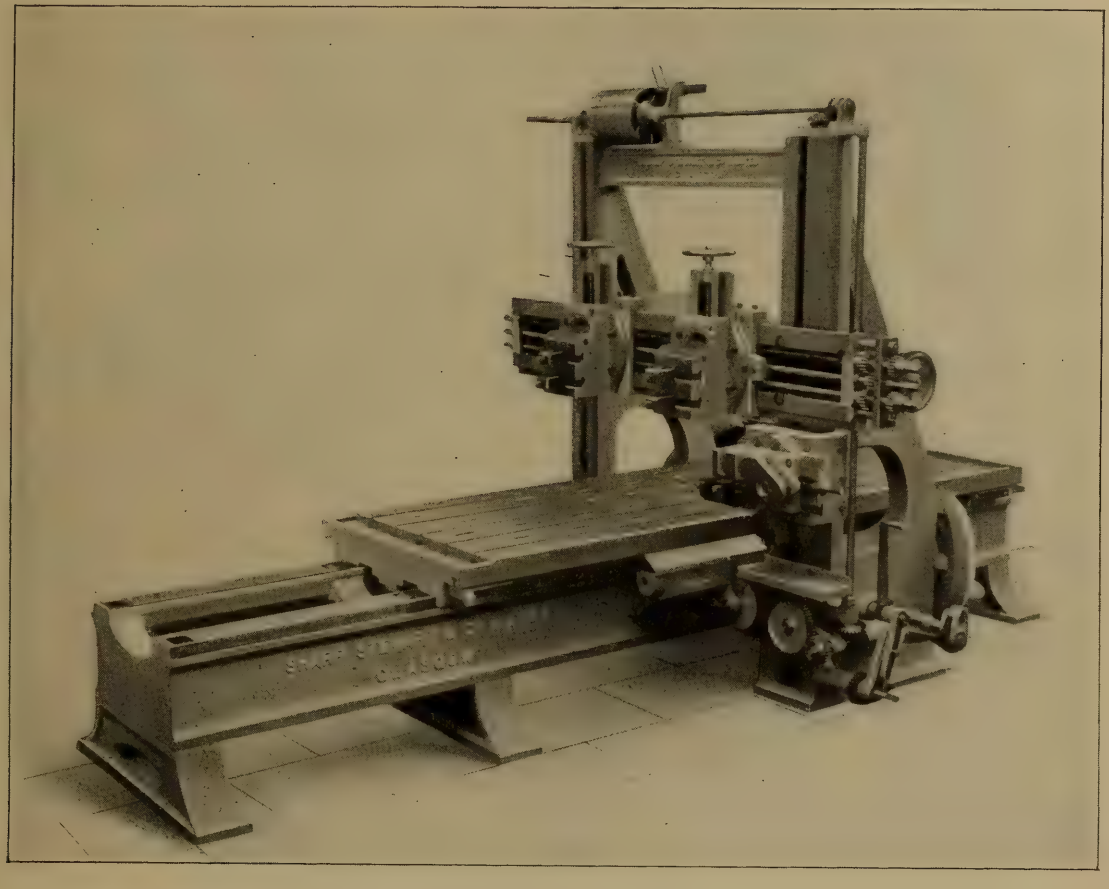


FIG. 4.—A PLANING MACHINE SHOWN BY MESSRS. SHARP STEWART & CO., LTD., GLASGOW

not rise when taking heavy cuts, for it is gibbed by plates *D* underneath.

The setting-up strips of the slide-rest are also fitted each as a single long wedge, tightened with screws from the ends. There are, therefore, no set screws along the edges, as in the common practice, and the setting-up strip in the top slide is on the far side, where it ought to be, instead of at the front.

ing in this instance six feeds ranging from 4 to 160 revolutions of spindle to the inch of travel of tool both for surfacing and boring, effected by the handles seen below the headstock. The change from single to double gear is now made through a friction clutch by a handle in front of the headstock while the lathe is running. The spindle is hollow, so making the lathe equally

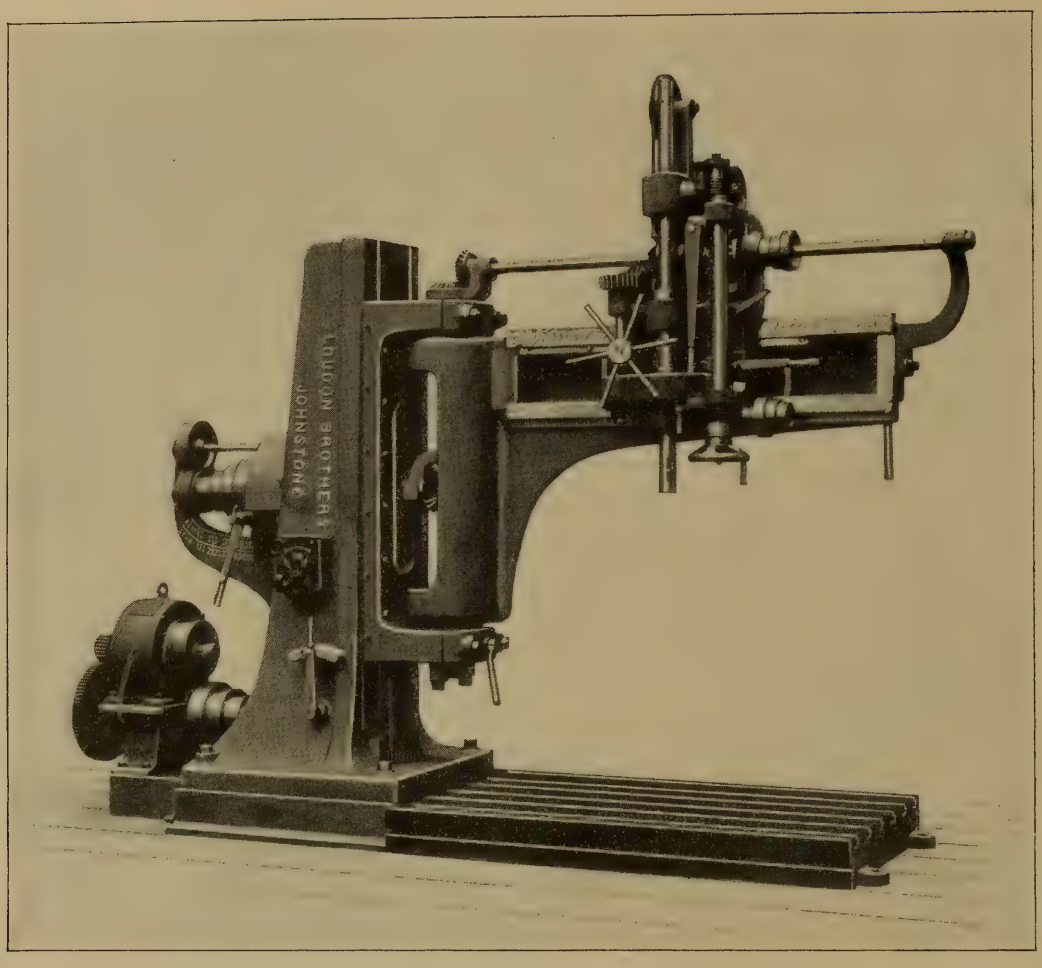


FIG. 5.—ELECTRICALLY DRIVEN RADIAL DRILLING MACHINE MADE BY MESSRS. LOUDON BROTHERS, JOHNSTONE

adpatable for bar work and for castings, for repetitive work as for miscellaneous jobs. It takes 2¼ inch stock, and is fitted with bushes for carrying the ends of boring bars. The bed is of the new type just described, with flat shears, and saddle fitting to the edges of the front one alone, with adjustment by taper gib in the manner already illustrated. This gives a longitudinal control of the edges six times greater than the width. The surfacing and longitudinal movements are both controlled from the front of the saddle, being stopped or started by the thumb-screw on the disc in front of the saddle.

The hexagonal turret has a large base, —13 inches in diameter. For each tool there is a separate stop for surfacing and traversing A good feature is that the turret can be moved out so that its centre has a greater radius than the swing of the lathe, actually to 16½ inches from the centre of a 15-inch centre lathe, with the result that the tool is well supported within the turret centre, and the stiff saddle affords adequate support to the latter.

A minor detail in the new lathes of this firm is worth noting. The usual flanges on the driving cone are omitted, so saving one moulder's joint in the small cone, and a little turning up. The gear wheel guards with which the heads are fitted are brought over just far enough to serve the same function as the usual flanges.

Conspicuous among the Lang exhibits is a shell turning lathe with duplex rests, Fig. 2, of which the firm has made between 200 and 300 within three years past, one ordnance-making firm alone having ordered over fifty at various times. The rest next the headstock is reserved for turning the parallel portion of the shell; that next the loose pop-

pet turns the curved portion by the concontrol of a radius bar. Formerly the lathes were made with the two rests carried on one saddle. In the present design the saddle is duplicated, with the advantage that the rests can be operated in unison or separately, that a heavier feed can be taken on the parallel part, and if the saddles are operated in different directions, end thrust is neutralised. One saddle is fed by a lead screw, the other by the back shaft.

Among planers, one by Messrs. Sharp Stewart & Co., Ltd., of Glas-

25 feet; and the reversal is perfectly smooth and noiseless. Another point in this machine is the broad feed,—up to 1½ inches maximum,—that can be imparted for finishing, the cutters being made of flat pieces of tool steel set at an angle in their holders. The tool boxes can be automatically fed in either direction, and the down and diagonal feeds are also automatic. The particular machine shown is of 4 feet by 4 feet by 10 feet capacity.

Among other tools by this firm note should be made of a fine slotting ma-

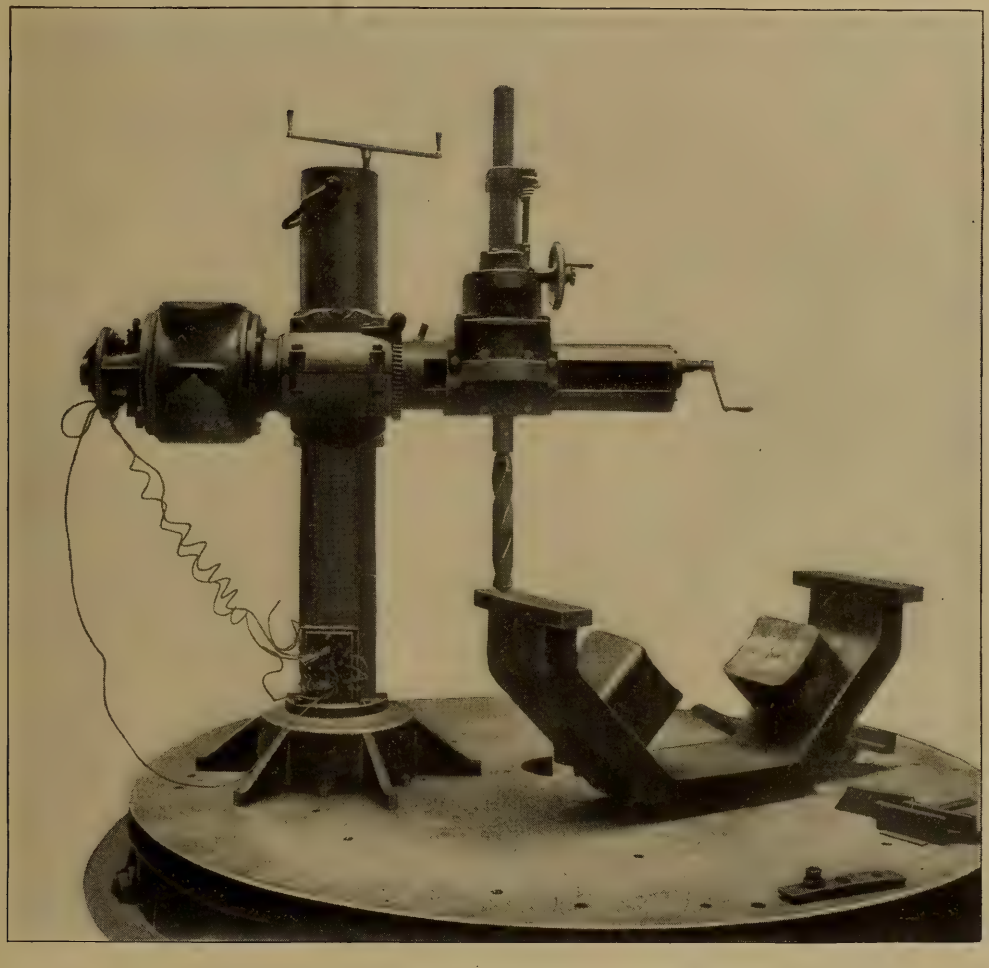


FIG. 6.—PORTABLE UNIVERSAL DRILLING MACHINE, ELECTRICALLY DRIVEN, MADE BY MESSRS. MATHER & PLATT, LTD., MANCHESTER

gow, shown in Fig. 4, marks the higher developments of this tool in Great Britain. It has the Sellers type of diagonal screw table-drive, with the actuating bevel wheels enclosed, and it is remarkable for its high rate of return, namely, 125 feet per minute, giving a quick return of 5 to 1, with a cutting speed of

chine, a heavy lathe of 27-inch centres, and a horizontal boring, facing, screw-cutting, and milling machine. These are characterised by solidity and excellence of workmanship, and by their general handiness.

Messrs. Loudon Brothers, of Johnstone, have some substantially built

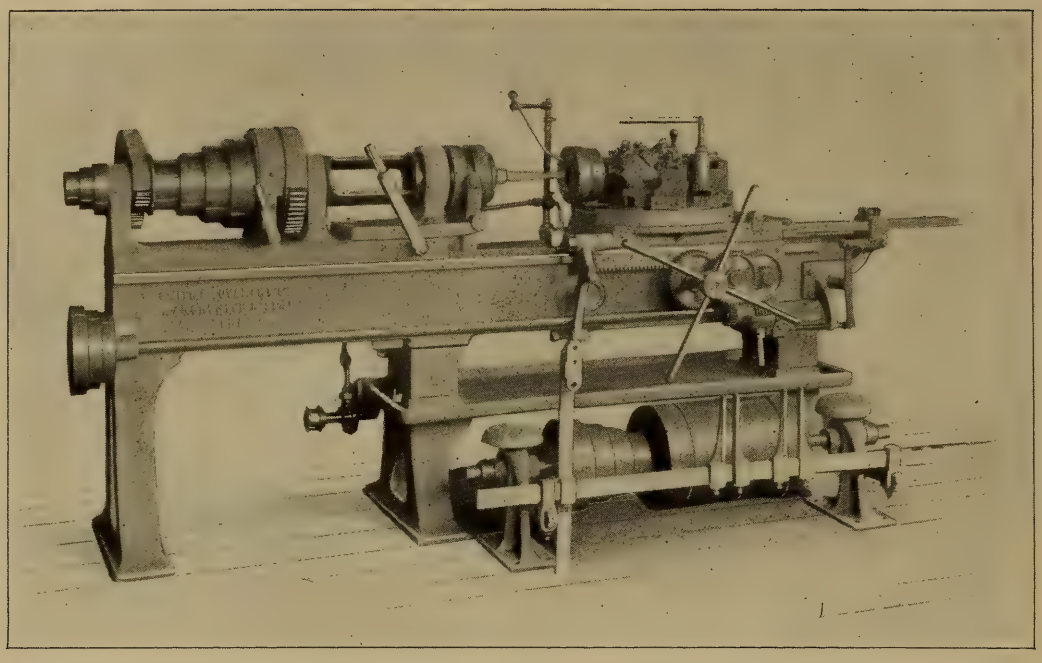


FIG. 7.—OPEN-SPINDLE LATHE WITH FLAT TURRET, MADE BY MESSRS. SMITH & COVENTRY, LTD., MANCHESTER, ENGLAND

tools of heavy type, the most recent being an electrically-driven radial drill, shown in Fig. 5. The motor is on the base at the rear, and speed is reduced by a pair of rawhide gears. The switch is at the side on the column. The back gear is internal and is changed by a lever, and the arm is raised or lowered by power. Drilling, boring, and tapping are done by the same spindle. Ball bearings are fitted to the radial arm.

Firms who do solid work as this of the Scotch tool makers, with some of their English confrères who exhibit alongside, can face the rising tide of American competition with equanimity. Their machines are too substantial, too handy, too well constructed, and too favourably known to lose their places in British shops, and the British visitor to Glasgow cannot help being conscious of a sense of pride and satisfaction when contemplating them.

An electrical portable drill, Fig. 6,

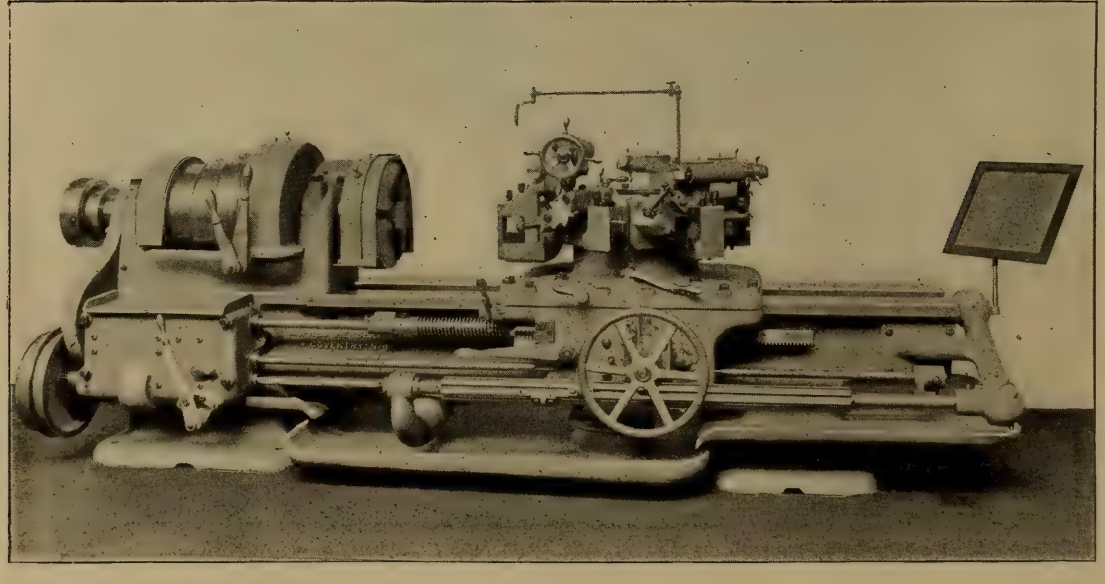


FIG. 8.—HEXAGON TURRET LATHE SHOWN BY ALFRED HERBERT, LTD., COVENTRY

attracts notice in the varied exhibit of Messrs. Mather & Platt, Ltd., of Manchester. It is a heavy tool with a 3-inch spindle for drilling holes up to 2½ inches in diameter, driven by a motor that develops 2 H. P. at 800 revolutions per minute. The main pillar is 7 feet high and 12 inches in diameter. The drill is absolutely universal in its movements. The radial arm,—8 inches in diameter,—is adjustable vertically on the column around which it swivels in a complete circle. Besides this movement in a horizontal plane, it swivels in a vertical plane on a face of the socket that slides on the pillar. The radial arm also can be swivelled on its own axis for angular drilling. The arm carries the motor at one end. This serves to counterbalance the strain due to the overhang of the drilling head that traverses along the arm, and upon which it is clamped in any position. The driving gear is contained in this arm. The spindle is fed vertically either by power or by hand. Back gears of 3 to 1 are fitted, and the spindle runs at 90 or 30 revolutions per minute with the motor at full speed. Lower speeds are obtained by regulating the speed of the motor.

The electrical arrangements include an electro-magnetic method of attachment to the base instead of by bolts, so that work laid upon an iron base can be drilled without bolting the machine down. The current to the magnet is arranged in such a way that the act of starting the motor also magnetises the holding-down coil. The motor is connected to the switch at the base of the column with a flexible cable that keeps the connection free in any position of the arm. It is wound to suit 100 to 200-volt circuits, as required. The resistance is in the base of the column where it is safe from damage.

A number of small German electrical drills are shown by the Electrical Company, Ltd., of London, the German manufacturers being the Allgemeine Elektricitäts Gesellschaft, of Berlin. The motors are at the rear, on the base, driving to a belt pulley, thence to a top belt pulley and bevels to the spindle. Other electric drills at the same stand have spindles to drill at an angle.

It is significant how prominently turret lathes figure at Glasgow. There is such a variety in design, and some considerable originality in detail, but there they are from the smallest and lightest to the heaviest for dealing with bars and castings. Besides well-known and favourable types, such as the Gisholt, the Herbert, the Jones & Lamson, etc., we find others, shown for the first time.

Our indispensable old friend, the open-spindle capstan lathe, by Messrs. Smith & Coventry, Ltd., of Manchester, Fig. 7, now has its range of utility increased by the addition of a flat turret which permits bar work to pass over the top instead of to one side, and by a new design of chuck. The mechanism of the latter provides for variation in the size of bars of as much as a good ⅛ inch from the normal sizes, which is of great advantage when black bars vary in dimensions. The flat turret is fitted for six tools, each with its own independent stop. A new chasing appliance is self-opening at the termination of a thread, and is closed by a hand lever, which permits of a roughing and a finishing cut being taken. The turning tool holder is opened and closed quickly by hand lever, the work being supported against the vee type of steady. Tools are made for right and left-hand work. One specific use of the lathe is the turning and screwing of locomotive boiler stays, to suit which two chasers are fitted on opposite sides of the turret for screwing opposite ends of the stays.

The exhibit of Alfred Herbert, Ltd., of Coventry, is second to none in the Machinery Hall. The new No. 4 hexagon turret lathe for bar work or castings, Fig. 8, the largest yet made by the firm, is shown for the first time. It admits bars up to 3½ inches through the spindle and chucks, will turn up to 48 inches in length, and is of 12-inch centres. The spindle is fitted with two chucks, one at the front and one at the rear, the latter for bars, while forgings and castings can be handled by the one in front. The spindle has eighteen speeds, six for each step on the cone pulley, obtained

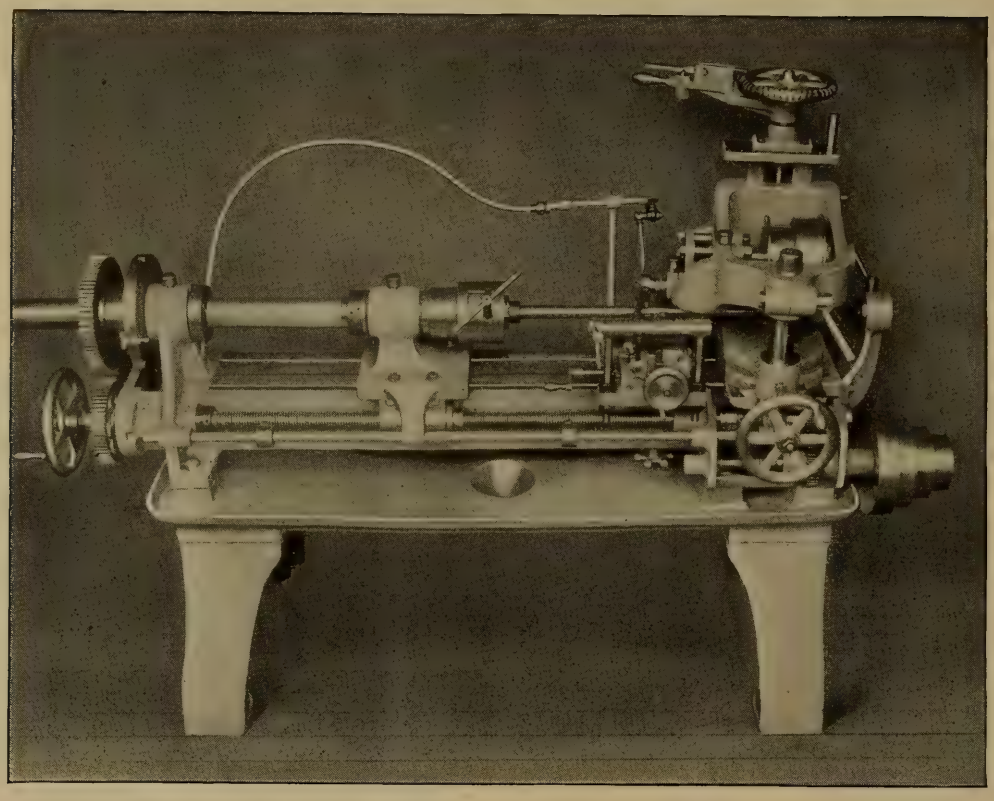


FIG. 9.—LIEBERT'S SCREW MILLING MACHINE, SHOWN BY MESSRS. JOHN HOLROYD & CO., LTD., MILNROW, NEAR ROCHDALE

by moving a lever, and each is reversible. The head is friction back-geared. There is power feed to the carriage, and a quick return by power. The turret, though so massive, is easily revolved by hand on a ball race. It has a separate trip and stop for each tool. The various movements, those for the feed, for quick power movement, and chasing, are so interlocked automatically that two motions cannot be engaged at one time. In the general design and details the lathe is built after a type which is now quite familiar.

The Liebert patent screw milling machines exhibited by Messrs. John Holroyd & Co., Ltd., of Milnrow, near Rochdale, are too recent to have become generally known to engineers. But they are already in use in several leading British and German shops for making armour plate bolts, worms, press screws, cotton machinery screws, etc., and they require only to be known better to be appreciated. The method of cutting screw threads with revolving milling cutters has much in its favor, particularly when multiple threads are in question. The difficulties of grinding and setting a single cutting tool, and of restarting a cut in its exact position, and the large amount of power required for multiple threads of steep pitches, are well known; but these difficulties are avoided in the milling type of cutter. A full description of the method of operation of these machines is not possible in the space at disposal here, but the illustration given in Fig. 9 must supplement the outline remarks to follow.

Though three types and sizes of machine are built, similar leading principles are embodied in each. The bar or blank on which the screw is to be cut is gripped in a suitable chuck which is revolved and fed along a bed, at a rate suitably proportioned for different threads, by means of a lead screw and change wheels. A hollow tube or spindle in the two larger machines is the medium through which the motion of the lead screw is communicated to the work which passes through it, for it carries the chucks, and is itself carried in a fixed bracket at one end of the bed. It moves along with the sliding car-

riage, being revolved by a worm and worm-wheel, and is driven from the guide screw by means of a train of change gears as in an ordinary screw-cutting lathe.

The mechanism for operating the milling cutter has a more complicated appearance in the illustration than it possesses when seen in action. It is carried in a headstock which swivels and has vertical adjustment, and the

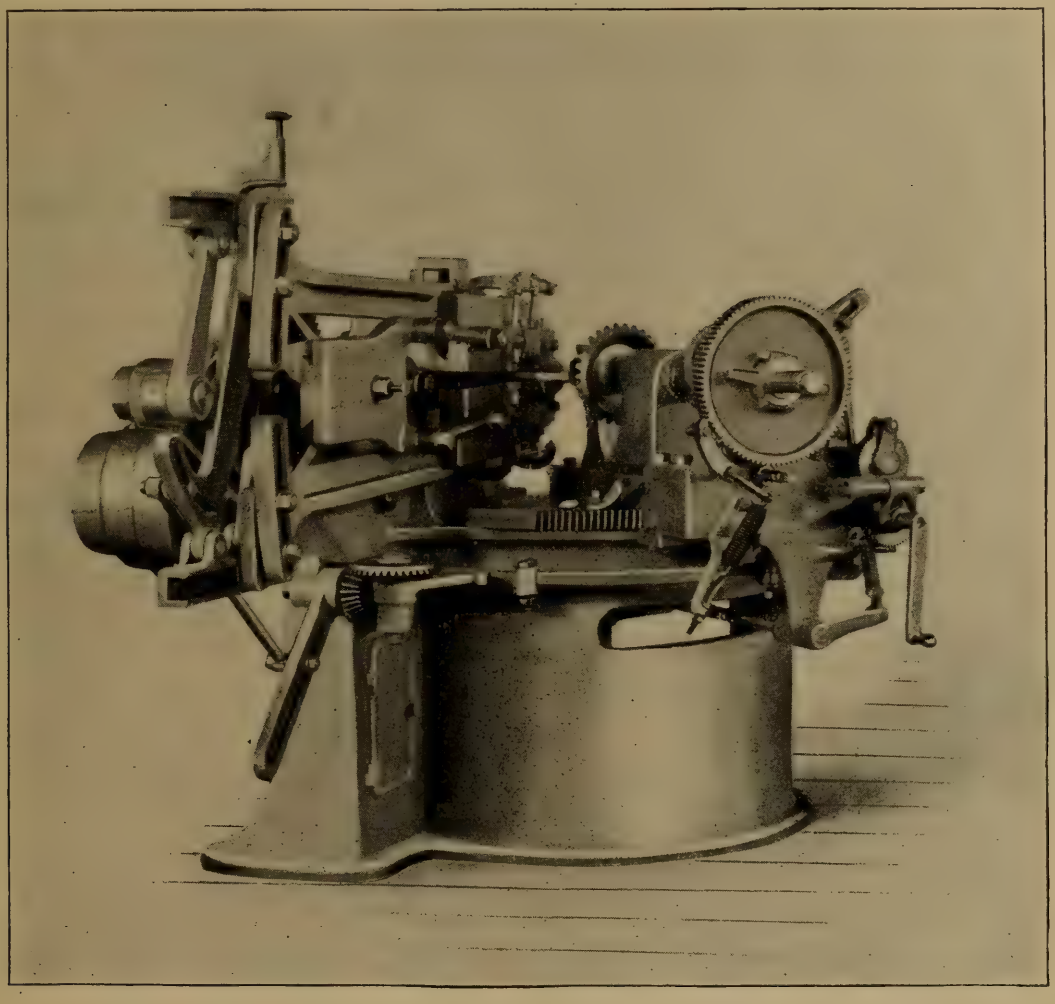


FIG. 10.—BEVEL GEAR PLANER OF THE GENERATING TYPE SHOWN BY MESSRS. SMITH & COVENTRY, LTD.

cutter is driven through gearing from a two-speed cone pulley. The different angles that are necessary for screws of varying pitches and diameters are imparted to this swivel headstock in the two larger machines, but in the smallest the table or carriage that swivels on the knee is set to angle. No calculations are necessary for this setting, for blue prints are supplied which give the attendant the angle required for screws of all pitches and diameters within the range covered by the machines. The hand wheel, seen notched above the headstock in the two larger machines, furnishes the means of regulating the depth of thread to be milled, and there is also a quick-adjustment down-feed screw, worked by hand. The cutting feed is derived from speed cones, driving a back shaft and change gears. After the machine is set up and started, the action is fully automatic until thrown out by means of stops, so that it is possible for one man to attend to from eight to twelve machines, the number being dependent on the length of the screws being made. At the termination of a cut the head has to be lifted by hand, the quick return started, and when the screw is of considerable length

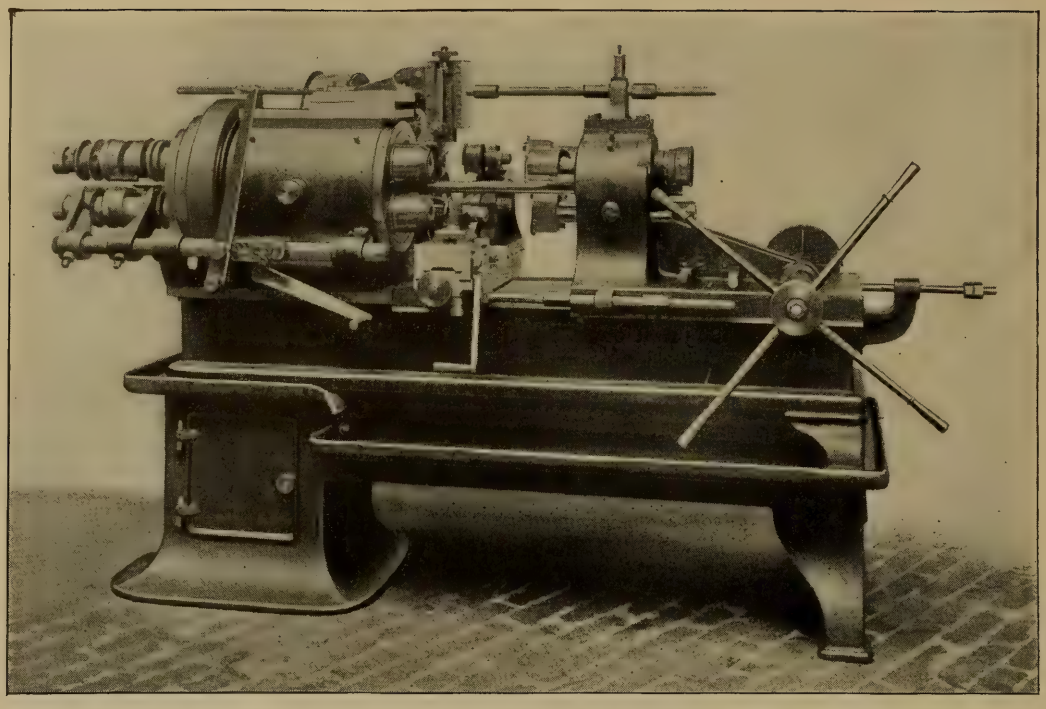


FIG. II.—FOUR-SPINDLE SEMI-AUTOMATIC LATHE SHOWN BY MESSRS. BURTON, GRIFFITHS & CO., LONDON

the machine is left again until the end is reached, after which the head is set once more.

Thus much for the general method of action of these machines. In the three sizes made they cover a range of screws from a maximum on the smallest type of 1 inch diameter by 6 inches length, to a maximum on the largest of 2½ inches diameter and 4 feet length. Worms may be cut up to 5 inches diameter, pitches up to 2 inches, and any threads from single to quadruple. In the case of very steep multiple threads of square section it is necessary to use a single threading tool to follow after the milling cutter in order to finish the vertical edges, for which a compound slide rest is provided on the largest machine When multiple threads have to be cut, two cutters may be rigged up to operate simultaneously. The pitch for multiples is given by a notched plate, without the trouble of measurement and trial. The small machine differs widely in the working out of its design from the two larger types. This is built after the milling machine model; the latter we may term lathe types. The first is especially designed for brass work.

Another automatic worm milling machine is the Cleveland, exhibited by Messrs. C. Churchill & Co., Ltd., of London, and the fact that this method of cutting threads is exemplified by machines having little else in common but the underlying principles embodied appears to mark a departure from present practice that may be an important one. Milled threads should be cheaper than those which are produced by a single-edged tool, ground and set by hand to the angle and depth required. If milling is better for some classes of work than planing, shaping, slotting, and even turning, it may hold great possibilities in screw and worm cutting. The milling cutter has a much longer life than the single tool. One man can attend to four or five of the Cleveland machines, but cutting worms in the usual way absorbs the whole attention of a turner. As involute worm threads have straight flanks, with or without a trifle of rounding next the points, it is quite easy to make relieved milling cutters of the proper shape for every pitch, the sectional form of which will remain constant until they are worn down.

The worm in the Cleveland machine revolves in a fixed axis; the cutter slide travels through change gears, being

driven by a telescopic shaft at any angle, to suit worms of different diameters. The proper angle of the cutter is set by a graduated arc, and the depth by a boss divided round. The cutter is driven at a higher speed than the worm. By means of a reversing lever, right and left-hand threads can be cut, each with single, double, treble or quadruple threads, and provision is embodied in the mechanism for equal division, so that the threads will be correct. Lastly, when a worm is finished, a bell is rung by the machine. The capacity of the machine includes worms from 1 inch to 4 inches diameter, and of any length up to 6 inches.

The trend of modern bevel gear cutting is illustrated at Glasgow in the presence of two machines of the planer type,—one an Oerlikon machine from Switzerland, and the Roby-Smith machine, by Messrs. Smith & Coventry, Ltd. The first has been previously illustrated in this magazine, in November, 1900, in connection with the Paris Exhibition; the second is shown in Fig. 10. It is one of the most cleverly designed machines of the generating type, yet it is so simple in operation that a lad can fix it up, setting by the graduated edges and the table of degrees provided.

Two ordinary planing tools are carried in reciprocating arms, which are coerced by slides at an angle, and these plane the teeth to the proper bevel to correct involute forms by the synchronous movements of the arms and of the wheel blank. Between strokes the blank is carried round an arc of revolution equal to the pitch, and after the whole of the teeth are gone over thus the blank is carried through a horizontal arc which slightly changes the angle of cutting. The levers by which the movements of the cutting arm are produced comprise an ingeniously devised parallel motion.

Messrs. Burton, Griffiths & Co., of London, show a Swedish four-spindle, semi-automatic lathe, Fig. 11, designed to carry on four pieces of work on four spindles, each of which is brough round, in turn, to be operated on by four tools in holders that are in alignment with the spindles. The idea is to quadruple the work of the common lathe or screw machine without increasing the cost for attendance.

The work spindles are enclosed equidistantly in a cylinder that is rotated by a toothed ring having external and internal teeth, the first receiving motion through cones and back gear, and the second transmitting it to the spur wheels that encircle the spindles. The tools are carried in holders that pass through the head of the tool carriage, which is moved by rack and pinion by hand, or by power, and has automatic stops. A cross slide carries two tool holders.

Of course, in this Exhibition we meet with many standard tools which must be passed by without notice, simply because they are so well known and have been described so frequently. Each of the four great British agents for American tools have very large groups of tools of nearly equal merit. Though we have noticed novelties chiefly, and not all of these, either, yet numerous improvements are noticeable on some of the older standard machine tools.

THE EVOLUTION OF STANDARDS OF MEASUREMENT

By John A. Brashear

ALTHOUGH the science of metrology has been a factor of immense value in the development of the human race, it is a most difficult and very unsatisfactory task to trace it back to its earlier history. There is little doubt, however, that some simple system of measurement must have been associated with the evolution of man from the savage to the civilised state. Indeed, may not the savage have need of some crude standard to lay out his habitation, be it in the forest or in the rocks? Perhaps in the far distant past our ancestors stepped off their possessions in the three-foot stride so often used at this late day, and the mothers of ten thousand years ago may have measured the length and breadth of their primitive garments with the thumb nail, finger length, or elbow length.

It is the writer's purpose here to refer more particularly to what may be called the development of linear measures, or measures of length; for, although there seems to be, even in the early history of measurements, a greater or less association of one measure with another, indeed, in many cases, one derived strictly from the other, yet the subject in these various relations would be entirely too extensive for an evening's discussion.

In the sixth chapter of Genesis we have the first Biblical reference to a standard of measurement:- "And God said unto Noah,—make thee an ark of gopher wood; rooms shalt thou make in the ark, and thou shalt pitch it within and without with pitch; and this is the fashion which thou shalt make it of:—the length of the ark shall be 300 cubits, the breadth of it, 50 cubits, and the height of it, 30 cubits." This, reduced to the Talmudist cubit, would give the ark a length of 546 feet, a breadth of 90 feet, and a depth of 54 feet 6 inches. If we are to accept Biblical chronology, the ark was built about 4800 years ago; but even Biblical chronologists differ by more than a thousand years for this date.

Be this as it may, giving it, indeed, the longest period assigned by any chronologist, we must go back to a still more remote period, when civilisation had covered the prolific delta of the Nile, for, long before the date of building the ark, we know that Egypt had made marvellous advances in the arts associated with hydraulic engineering, the construction of massive and magnificent architectural work, surveying of a very accurate character, and many other attainments that must have demanded no small degree of precision in their instruments and methods of measurement. But how far back into the distant past, many centuries before the great Pyramids were built and the great Sphynx looked out over the sands of the desert, must we go to reach the dividing line, if such it can be called, between civilisation and savagery in the delta of the Nile, or how far back must we go to the time when men had no need of measuring instruments to meet the demands of their various callings? So far as we know at present, the standard measuring instrument for linear measures in Egypt, Persia, Babylonia, Greece, and, in fact, all the Eastern countries, was the cubit, which was di-

vided in various ways, that of the Talmud being divided into digits, or finger breadths, palms, and spans, four digits being equal to one palm or hand breadth, three palms to one span, and two spans to one cubit.

A great deal of valuable research has been made by eminent metrologists to ascertain the length of the cubit as used by the various nations who made it their standard. We would naturally imagine that all cubits were of one length, but when we consider that our own foot measure has varied so much (nine and a quarter inches) from its present recognised value, we should not be surprised to find that the cubit varied from 18.23 to 25.1 inches in Egypt. The cubit of the IV. Dynasty varied from 20 62 to 20.51 inches,—only about one-tenth of an inch. The divided plotting scales lying on the drawing board of the statue of Gudea equaled 20.89 inches. The Babylonian cubit was almost exactly of the same length as the Egyptian cubit of the IV. Dynasty, viz., 20.6 and 20.5 inches. The Persian cubit seems to have been rather short, measuring 19.2 inches; but, according to a recent writer, there is good evidence of another cubit, measuring about 25.25 inches.

The cubit of the Hebrew nation, according to a number of investigators, seems to have been 21.6 inches, although Lieutenant Totten insists, and seems to have proved, that the value of the Jewish, as well as the Egyptian sacred cubit, was exactly 25 inches.

There is considerable difficulty in connecting the links between ancient and medieval metrology, for no sharp lines can be drawn, and there is a period of more than a thousand years over which the connection of units of measure is very uncertain. The Belgic foot was probably carried over to Great Britain in the tenth century. Its value, as the foot now measures, was 13.22 inches; but it had to come in contact with the legal foot, which was enforced by law as early as the year 950. Had the Belgic foot of 13.22 inches been adopted instead of the legal foot of 12 inches, only a very small change would have to be made to make it one-third of a metre, the metre being about 39.37 inches, and three times the value of the Belgic foot would be only 0.29 of an inch longer than the metre. But the edict of King Henry I. had placed the value of the foot at 12 inches, or one-third of the legal yard, which, in turn, was supposed to be one-half the distance between the tips of the fingers of the outstretched arms of King Henry. In the year 1324 A. D., in the reign of Edward II., a statute was enacted that made the standard inch equal to "three barley corns round and dry," and twelve such inches made one foot. Who of us that have lived out our half century do not remember the old long-measure table commencing with, "Three barley corns make one inch"? I believe the long-measure tables no more contain this familiar sentence.

There were several values of the yard in the interval between King Henry's time and that of the final value which was established just five hundred years after what may be called the "barley corn" statute. There was the yard and handful, or 40 inch Ell, which was abolished in 1439; the yard and inch, or 37-inch Ell, which was abolished in 1553; the cloth Ell of 45 inches, which was used until 1600; and the yard of Henry VII., which had a value of 39.963 inches, within thirty-seven thousandths of the value of the yard and handful.

But the mechanic arts cried out for a better standard, one that was not so variable as the barley corn, or the length of a man's arm, and so early as the beginning of the seventeenth century most accurate standards of the yard, foot, and inch had been graduated upon metal bars by Abram Sharp, Rowley, Sissons, Smeaton, Graham, and others, all of whom contributed by their various methods to a very high development of the adopted standard.

Just five hundred years after the statute of Edward II. which made the barley corn the basis of the inch, it was, by an Act of George IV., in 1824, that a legal definition of the yard was made. This declared that the yard bar, made

by Bird, in 1760, should be the standard beyond any question or doubt. The first section of this Act, as given in Mr. George M. Bond's excellent work on "Standards of Length," was:—"Be it enacted * * * * that from and after the first day of May, one thousand eight hundred and twenty-five, the Straight Line or Distance between the Centres of the Two Points in the Gold Studs in the Straight Brass Rod, now in the Custody of the Clerk of the House of Commons, whereon the Words and Figures, 'Standard Yard, 1760,' are engraved, shall be, and the same is hereby declared to be, the Extension called the Yard; and that the same Straight Line or Distance between the Centres of the said Two Points, in the said Gold Studs, in the said Brass Rod, the Brass being at the temperature of Sixty-two Degrees by Fahrenheit's Thermometer, shall be, and is hereby, denominated the 'Imperial Standard Yard.'"

There have been many controversies as to what is the real basis of British measure. Many claim that, notwithstanding the various edicts of England's kings, the real basis came from some natural, or what Lieutenant Totten calls an "earth commensuric standard," and this basis Piazzi Smyth, that pioneer of pyramid study, most ardently supports. The writer had the pleasure of knowing Prof. Smyth, and became conversant with his labours, as well as those of Lieutenant Totten, and believes them to have been earnest and honest in their endeavours to convince the world that in the Pyramids we can find no other unit of measure but the British inch, and the sacred cubit of 25 inches, made up, of course, of multiples of the smaller standard, which, according to their determinations, makes our present standard inch but one-thousandth different from the standard, as given by them. They trace the origin of the inch to be one-five-hundred-millionths of the polar axis of the earth. It is beyond the province of this article to discuss this curious question, but the views of both these students of metrology are generally considered as having no basis whatever except that of coincidence,—rather an unstable foundation in such an important problem.

The French system of measurements was in almost hopeless confusion up to the end of the eighteenth century, for, in 1790, there were thirteen different "pieds," eighteen different ells in linear measures, and as many differences in weights and other measures. The same condition of affairs existed in Germany and Italy, and it is little wonder that some standard should be called into existence. Huygens had suggested the length of the pendulum beating seconds as a standard of length, and in the year 1790 Prince Talleyrand brought before the French National Assembly a proposal to abolish the old system of weights and measures, to be in whole, or in part, replaced by a new system founded upon the length of the pendulum beating seconds. A committee, consisting of such eminent men as Condercet, Borda, La Grange, and La Place, was appointed, and, after five months of deliberation, they reported in favour of a scheme which was practically the metric system as we know it.

For the linear measure three natural standards were considered:—1st, the pendulum beating seconds; a quadrant of the equator, and a quadrant of the earth's meridian. It is believed historically correct that Mouton, an humble priest of Lyons, had worked out a system of standards based on the length of the pendulum beating seconds a hundred years before the meeting of this illustrious commission. A second commission was appointed to determine the values of the various standards as suggested, but before they had finished their work, the National Assembly lost patience and passed a law making the new system compulsory and to go into effect immediately, the dimensions of the standards having been hastily computed from previous measurements. Mr. George W. Colles, of the United States Patent Office, in a most excellent paper on the metric *versus* the duodecimal system, has this to say of that commission, which did such splendid work in the determination of the stand-

ard during the fiery period of the French Revolution:—

"I need not dwell on the political details of that period, but from those bloody and fanatical scenes not even the abstruse and impartial labours of mathematics and mechanics were exempt. Mechain was made a political prisoner in Spain; Lavoisier, one of the most brilliant and active members of the commission, and an associate of the first commission, was guillotined, with twenty-seven others of his profession, in the idea that 'the Republic had no need of savants.' This was the actual reply to those who begged for the life of Lavoisier. Condorcet, the first chairman of the commission, poisoned himself in prison to escape a similar fate. Borda, La Place, Coulomb, Brisson, and Delambre were dismissed from the commission, and barely escaped with their lives."

Yet even Robespierre and his committee were ambitious to establish the new system of weights and measures and offered them for adoption by other nations, and on August 2, 1794, two standards were sent to the Secretary of State in America, with urgent requests for their adoption. Thus was born the metric system of weights and measures which has slowly made its way among the nations.

Perhaps one of the most important factors in the evolution of methods of division and accurate measurements was brought about by mechanicians interested in clock-making. These were, no doubt, developed from smiths, brasiers, and other mechanical workers, but up to the beginning of the seventeenth century no instrument makers, as such, were known. Abram Sharp, an Englishman, was perhaps the first to cut accurate divisions in astronomical instruments. It is said that Bird, a country lad, became interested in accurate dividing by seeing the irregular spacing on a clock face. He became one of the best known of the early workers in dividing accurate astronomical instruments. Tompion, Rowley, Graham, Sissons, were all contemporary with Bird in his earlier or later life.

About the middle of the seventeenth century the demands of astronomy became almost imperative for a higher grade of instruments, particularly those designed for the measurements of celestial arcs. Up to that date all circles had been divided by hand, and there is little doubt that the most consummate skill was required in this, one of the most exacting demands in astronomical science. Astronomers had for some time divided their own circles, quadrants, sextants, etc.; indeed, it is very difficult to say how far back this kind of work had been done, for there are still elaborate and wonderfully made instruments in existence in the old Chinese observatories that were made many hundred years ago.

As has been remarked, all the earlier astronomical instruments or circles were divided by hand, and some of the circles divided by Sharp, Graham, Sissons, Bird, Ramsden, Troughton, Simms, and the Duc de Chaulnes may be found in existence to this day. Graham, and, in fact, all who divided circles by hand up to the time of Troughton, used the beam compass to lay off their divisions. Graham laid it down as an axiom that it is possible to bisect any arc with precision practically, but it could not be trisected or quinquisected. This rule was generally followed by his successors, but some circles were divided by trisection and quinquisection. Troughton divided his circles by continual bisections. The arc of 60 degrees was readily stepped off, as we all know that the radius of any circle is the chord of an arc of 60 degrees on the circumference of the same. Bisecting the arc of 60 degrees, the 30-degree mark was obtained. Stepping off 30 degrees from the 60-degree mark, we have the sum of the two, or, 30 plus 60, equals 90 degrees; bisecting 30 degrees, we have 15 degrees, which, stepped off from the 60-degree mark, gives us not only the 15 degrees, but 15 plus 60 equals 75 degrees, and 15 degrees stepped off from the 30-degree mark gives 45 degrees, and so through the entire range of divisions.

Although the differential expansion

and contraction of the metals of circles was apparently not recognised in the earlier dividing, yet, in Troughton's day, about 1790, it was considered an important factor. The beam compasses with which his dividing was done were always laid upon the circle when not in use so that they might assume the same temperature. The points of the beam compasses were exquisitely made, and a magnifying glass was always used to make the delicate marks and bisections necessary in dividing the circle. The division lines were sometimes made by the use of a straight-edge, which rested against a pin in the centre of the circle and over the dot made by the point of the beam compass; then a peculiarly shaped cutting tool was drawn between two or more bounding lines. Sometimes the marks were made by setting the point of the beam compasses in such a way that, by drawing them through the points already laid out, a short, curved line would be made, the curvature not affecting the precision of the divisions.

It would be impossible here to do justice to the noble corps of men who were the pioneers in this difficult work, for we must not forget that the splendid dividing engines with which all accurate astronomical dividing is done at the present time are, in reality, refined copies of this original hand-work.

But the demand for greater precision and an unlimited supply of sextants and other instruments of precision became so great that Ramsden brought out his automatic dividing engine in 1771, although Hindly, of York, had made an automatic dividing engine for cutting the teeth of clock wheels as early as 1740. The Duc de Chaulnes was contemporaneous with Ramsden, and produced an automatic dividing engine with some valuable improvements. After Ramsden had completed his engine he received many orders for graduating sextants and quadrants, but he seemed to become indifferent to this part of the work and neglected many of his patrons. About that time Troughton completed his automatic dividing engine, which proved to be a remarkable success, and he and his brother were soon crowded with orders for sextants, circles for meridian instruments, etc. Later on, they made a smaller, but very accurate, engine, as it was found very difficult to set and adjust the circles to be divided upon the larger one. Troughton divided some of the very best circles to be found at the beginning of this century, and the writer believes many of the meridian circles divided by him and his associate, Mr. Simms, to be still in use and doing good work.

At the present time there are not many high-class dividing engines in the world. The Repsold engine, in Hamburg, has, perhaps, divided a greater number of more accurate circles than any of the more modern dividing engines. This engine can hardly be classed as automatic, and a member of the present firm told me, when I visited the workshops in 1892, that three successive generations had spent the best years of their life in an endeavour to eliminate the errors of this famous engine. I believe the mean tabulated error of the best circles divided with this engine is about 1.6 seconds of arc. The Repsold, Ertel & Son, Pistor & Martens, and Bamberg dividing engines, in Germany; the Gautier, Gambey, and Secretan engines, in France; the Simms & Troughton, and Cooke engines, in Great Britain; and Sir Howard Grubb's engine, in Ireland, are, the writer believes, the most accurate engines in the Old World. In the United States there are the Wurdeman & Saegmuller engines, at Washington; the Stackpole engine, at New York; the Buff & Berger, at Boston; and, finally, the Warner & Swasey engine, at Cleveland, Ohio.

The last named engine was constructed with a full knowledge of all that had preceded it, and also with a comprehensive understanding of the vagaries of the material, and the environments that would necessarily surround the engine when at work. This beautiful machine, beautiful from the point of view of the splendid work it is doing, has cost the labour of years and the expenditure of a large amount of

money; but it is a great satisfaction to know that, after a careful and critical study of the final set of divisions made upon one of its inlaid silver circles by that eminent investigator, Prof. Morley, the mean of its errors are found to be less than one second of arc.

Ramsden and Troughton constructed linear dividing engines after they had completed their circular dividing engines. In one of these linear dividing engines they reached an accuracy which was quite beyond the demands of the mechanical work of that epoch; but this state of affairs was not to be of long continuance, for it is characteristic of human affairs that one phase of development cannot go along without carrying others of a correlated nature with it. Most accurate standards of measurements were in the hands of various governments, but had not found their way into the hands of the mechanician.

We must give to Whitworth unstinted praise for the splendid work he did during the first half of the present century to make and introduce measuring tools of great accuracy into mechanical manipulations. His millionth measuring machine has become famous as the model after which many later machines have been constructed, although it is doubtful if even so great a man as Whitworth reached the precision he claimed with this instrument. Nevertheless, it was his unswerving purpose to eradicate all slip-shod methods in the workshop, to throw "barley corns" to the birds, and place in the hands of his workmen measuring instruments and tools of precision whereby they could not only finish their work to the ten-thousandth of an inch, if necessary, but reproduce it again and again. In this manner was the dawn of the millennium of interchangeable parts in machinery ushered in which is now shedding its beneficent light to all the world.

It has been stated that two nations had adopted standards of weights and measurements. Great Britain adopted the yard of 36 inches, which was, by Act of Parliament, the length between the bounding points on a brass bar ruled by Bird in 1760; the foot, which was one-third the length of the yard; and the inch, which was one thirty-sixth part of the yard. The standard of France was the metre and its subdivisions, the decimetre, centimetre, and millimetre. The basis of the metre was one ten-millionths of a quadrant of the earth's meridian, primarily, and the length of a pendulum beating seconds at Paris. Many other standards had been proposed. Sir John Herschel had proposed the length of the polar axis of the earth as the unit, for reasons that have a large scientific value. This value would have made the inch as nearly one five-hundred-millionths of the earth's polar axis as the metre is one-forty-millionths of the earth's meridian; but this was not adopted, although the attempts at determining the value of the earth's meridian soon showed that every degree of latitude varied in length from the equator to the pole.

It must be said, to the honour of the French nation, that they left no stone unturned to determine the true value of an arc of the meridian. MM Godin, Bouguer, and de La Condamin were sent to Peru during the reign of Louis XV., and, after ten years of labour, enduring great hardships and many privations, they succeeded in measuring an arc of the meridian extending over 3° 7′. Maupertuis, Clairaut, Lemonnier, and Authin reached the Gulf of Bothnia in 1736, where they succeeded in measuring an arc of 57′,—not quite a degree,—in sixteen months. The story of their stay in that frigid latitude is almost tragic in its interest, as it has been given to us in the "Life and Letters of Maupertuis," by Beaumelle. Suffice it to say, that, notwithstanding the immense labour involved in this work, which was, by the way, not done primarily as a basis for a standard of measurement, it has been shown that while a mean of all the measures taken makes the metre a very close approximation to one ten-millionths of the earth's quadrant, it is not absolutely so, and it matters little whether the metre be long or short of a certain relative length, so that its length is fixed once for all, and upon some basis by which

it can be reproduced. Then will it fulfill all the demands of modern metrology.

Many investigations were made to determine the absolute length of the pendulum, as it was found to differ with the latitude, the length varying about one-tenth of an inch in forty-five degrees. In the United States as early as 1790 Thomas Jefferson, then Secretary of State, in obedience to a resolution of Congress, proposed a system of weights and measures based on what is called a natural and invariable standard of length. He rejected the ordinary pendulum of 39 inches, and advised the use of a seconds rod of 5 feet, known as Leslie's pendulum rod. This was a straight rod, without disc or bob, suspended at one end and free to swing at that point, its centre of oscillation being at a distance of two-thirds of its length from the point of suspension. A rod of this kind vibrating seconds is, at the level of the sea and latitude 45°, a little in excess of 58.72 inches in length. Jefferson proposed to divide this into five parts, calling each part a foot, which would give 11.745 inches for the value of the foot. The foot was then divided into ten equal parts, thus bringing it into correlation with the decimal coinage of the country. This system never made any headway, and to this day the United States hold to the old British standard, at least, to a very large degree.

Ten years after the adoption of the British standard, *i. e.*, the brass bar divided by Bird, the house in which it was kept was destroyed by fire and the standard was ruined. Fortunately, there were a number of standards in the possession of the Ordnance Department of Great Britain; the yard of the Royal Society, by Kater, and the Shuckburg scale, which had been compared with the Bird scale of 1760 and found to agree closely. Sir Francis Bailey was entrusted with the work of reproducing the standard, but died before its completion. Rev. R. Sheepshanks then took up the problem, and after making almost 200,000 comparisons by the aid of the micrometer microscope, decided upon a mean of all the standards, which was reproduced upon a bronze bar now known as No. 1. This is a bar 38 inches long, 1 inch wide, and 1 inch deep. The graduations are upon gold plugs sunk in wells drilled in the bar so that the divisions shall be about the middle of the depth of the bar, for the reason that in this position flexure of any kind will have the least effect in changing the distance between the divisions. It was also found necessary to support these standard bars so as to produce a minimum effect in disturbing them, the formulæ for which were worked out by Sir George Airy.

Four copies of the original standard have been made, and are kept in different places, so that, should one be destroyed, the other three would still be available. By Act of Parliament, June 30, 1885, one of the forty copies made of the original standard was presented to the United States and is known as "Bronze Standard No. 11." It is deposited in the office of the Coast Survey at Washington. Careful comparisons made with the imperial yard show this bar to be eighty-eight millionths of an inch shorter than "Bronze No. 1."

The metre of the archives, or standard metre of France, is ruled on a bar of platino-irridium, and is kept in the buildings of the International Bureau at Breuteil, near Paris. As to the origin of this important institution, it may be interesting here to explain that in 1870 the French Government invited the various nations to an international standards convention, to be held at Paris. Seventeen nations were represented, including the United States, but not Great Britain. It was decided at the convention of 1875 to adopt the standard of the French archives. The two copies of the metre prototypes of the International Bureau were sent to the United States in 1889. They were drawn by lot, and the United States received Nos. 21 and 27. Great Britain joined the Bureau in 1884, but without any agreement to adopt the metric system; but the British people were not slow to see the value of the Interna-

tional Bureau, for there the standards are studied with scientific accuracy and under the most perfect conditions for carrying on researches in all lines of metrology. M. Bischoffsheim has presented to this Bureau a splendid comparator for the determination of linear values, and with the instrument equipment of this institution and the men in charge of it, work of inestimable value in the domain of universal metrology has already been accomplished. Early in the eighties Prof. Michelson, of Clark University, proposed as a new standard for determining the value of any linear measure, the length of a wave of light, which he and other physicists had determined with a marvellous degree of accuracy, and which will remain constant as long as the earth is travelling through the luminiferous ether. Prof. Michelson invented an instrument which he called the interferential refractometer, by which he could determine the number of light waves between any two points or lines in a standard bar. In this work he had associated with him Prof. Wadsworth, now director of the Allegheny Observatory, who went to Paris with Prof. Michelson, by the request of the International Bureau, to make a determination of the standard metre in light waves, the results of which have been published by the Bureau in a volume of many hundred pages. In this research the value of the metre was determined from waves of radiant energy of three different amplitudes; one from the red part of the spectrum, whose length equals 643,847 + ten-millionths of a millimetre; one from the green radiations, whose length equals 508,582+ten millionths of a millimetre; and one from the blue waves, whose length equals 479,991 + ten-millionths of a millimetre. The results of the value of the metre in these three wave lengths are as follows:—For the red, 1,553,163.5 waves; for the green, 1,966,249.7 waves; and for the blue, 2,083,372.1 waves.

The optical parts of the refractometer with which these measurements were made were constructed in the writer's workshops. The limiting error of the optical planes and mirrors with which the phenomenon of interference was produced was not greater than one-twentieth of a mean wave of light, or about one-millionth of an inch, or one forty-thousandths of a millimetre. This beautiful measuring instrument is now coming into use in many of the more abstruse and difficult problems of refined measurements, and it has been so simplified by Michelson, Stratton, and Wadsworth as to make it an invaluable accessory to the equipment of every physical laboratory.

When the writer began his apprenticeship in 1857 the measuring equipment of a machine shop was very meagre indeed, and it is a matter of wonder now that such excellent work was accomplished. The writer can well remember the interest that mechanics took in the demands of the United States Government during the early part of the American Civil War for accuracy in the bore of the cannons made at the Fort Pitt Foundry and Machine Shop. If I remember correctly, the Sellers and Betts gauges were introduced about that time. Soon it became apparent in the United States, as well as in Great Britain, that there was a crying need for a development of machine tools and methods of measuring so as to produce interchangeable parts, and be it said, to the honour of American scientific men and mechanicians, particularly of the New England type, that we had not long to wait for a solution of the problem. The writer can, perhaps, put this matter in no better language than that of Mr. M. N. Forney's report to the Master Car Builders' Association of the United States, at Philadelphia, in 1882. Mr. Forney said:—

"It is worthy of note that the evil complained of by master car builders, that nuts made by some firms, or at some shops, would not screw on bolts made at others, at first baffled the ability of the most prominent manufacturers of tools in the country, and, to provide an adequate remedy, it was necessary to secure the assistance of the highest scientific ability in the country,

which was supplied through the co-operation of the professor of astronomy of the oldest and most noted institution of learning in the land.

"The man of science turned his attention from the planets, and the measurement of distances counted by millions of miles, to listen to the imprecation, perhaps, of the humble car-repairer, lying on his back, and swearing because a 5/8-inch nut,—'a leetle small',—would not screw on a bolt a 'trifle large.'"

This man of science was Professor William A. Rogers. Perhaps no man ever worked with greater zeal in his chosen pursuit than did Professor Rogers, and to the end of his life he felt that he would like to reach a higher plane in methods of precision. He took advantage of every advance others had made in the science of measurement. Associated with Prof. Morley, he made use of the beautiful system of interference, as developed by Michelson, to determine minute measurements, and no other man more thoroughly knew the value of constant temperature conditions for work of great accuracy.

The government metrologists of Great Britain and France gave him every facility for studying and copying the standards of the two nations, as did also Prof. Hilgard and others connected with the United States Coast Survey, and his written works and papers, read before the various scientific societies of the United States, are now considered invaluable in the literature of metrology. He was conscientious to the extreme in his investigations. As an instance, in order to determine the idiosyncrasies of thermometers of various types, he made 22,000 readings of thirty thermometers, from the coldest to the hottest temperatures that any of the measuring instruments would be liable to undergo in use, and the writer has known him to get up at five o'clock in the morning many times and travel for a mile or more to the observatory in order to test his comparison bars when they had reached a state of quiescence.

Fortunate, indeed, was it that the Pratt & Whitney Company, of Hartford, Conn., secured the assistance of Prof. Rogers to supply them with standards from which they could produce gauges and other tools for exact measurement. Associated with Prof. Rogers in the mechanical work was Mr. George M. Bond, who, with Prof. Rogers, developed the splendid comparator, known to every master mechanic as the Rogers-Bond comparator. It would extend this paper beyond all reasonable limits to fully describe this instrument, which has done so much toward the development of the mechanism of standard dimensions and interchangeable parts in machinery everywhere. Suffice it to say that the principle upon which it is constructed is that line measurements from line standards may be transferred to end measures, and quick comparisons made of them, so that it is possible to make all standard gauges to within one forty or fifty-thousandths of an inch. It would be impossible to estimate the immense value of the admirable and beautiful work of the Pratt & Whitney Company in the development of mechanic arts in the United States. In the matter of standard screw threads alone the interchangeable system has saved hundreds of thousands, if not millions of dollars, to the railways of the United States.

To the Brown & Sharpe Company, of Providence, R. I., and particularly to the firm so long known as Darling, Brown & Sharpe, we are indebted for the beautifully and accurately made micrometer gauges and other measuring tools now to be found in the hands of every good workman. Micrometer calipers made by them with almost as much precision as an astronomical instrument are to be found in every well-regulated workshop, and their try squares, divided rules, and many other tools, needed by the finest mechanic, yea even by the apprentice of to-day, are made with a degree of accuracy totally unknown two decades ago. Workmen vie with one another in using these tools to produce the most accurate results, and as they have a perfect standard to which all measures

can be referred, the artisan is constantly cognisant of the fact that "he knows what he is doing." These tools are in demand in every part of the world where mechanics are to be found, and the name of Brown & Sharpe is synonymous with accurate tools everywhere.

Other American firms have, in recent years, added many fine precision tools to the list that are at the command of the mechanician. The writer can well remember when Mr. Starrett brought out his first measuring scales, continually adding to the number and accuracy of measuring instruments, gauges, try squares, micrometer calipers, micrometer squares, bevels, etc. Mr. Starrett has placed almost every needed practical device in the hands of American machinists and tool makers, and at a cost that seems astonishingly low when one considers the character of the work. This is told here simply with the view of giving due credit to the ingenuity and high ideal of these men who have done so much to place American workmanship upon a high plane. The writer is creditably informed by one of the foremost mechanical superintendents in Pittsburgh, who is of foreign birth himself, that in all Europe he has not found machinists' working tools of the high excellence that are made in the United States, and that not a micrometer caliper could be found in Germany of German make, although he is informed that a firm in Saxony have recently introduced such an instrument of their own manufacture.

The writer cannot close this article without saying a few words of the work of Professor Henry A. Rowland, of the Johns Hopkins University, in the construction of his linear ruling engine, which has done the most accurate ruling of any engine ever constructed. The ruling engine of Dr. Rutherfurd, of New York, had, in the hands of Mr. Chapman, produced some magnificent diffraction gratings as large as 2 inches, with about 35 000 lines ruled upon them, and every astronomer and physicist knows of the marvellous results obtained in spectrum analysis with the Rutherfurd gratings.

Professor Rowland set himself the task of constructing an engine by which gratings, three times the size of those made by Dr. Rutherfurd, could be ruled. After years of patient labour in eliminating errors of the screw by a method of his own devising, eliminating errors of curvature in the "ways" of the carriage that carried the grating, and in finding the best character of the ruled lines, he has succeeded in producing gratings of exquisite beauty and accuracy, ruled with ten, fifteen, and twenty thousand lines to the inch, and upon some of his larger gratings he has ruled as many as 120,000 lines, with a precision never before dreamed of. It is said that in some of these gratings an error so great as one two-millionths of an inch does not exist between any two adjacent lines. The marvellous product of this engine has opened up new and hitherto unexplored fields in the realms of spectrum analysis.

FROM LOGS TO PAPER

THE LARGEST PAPER MILL IN THE WORLD

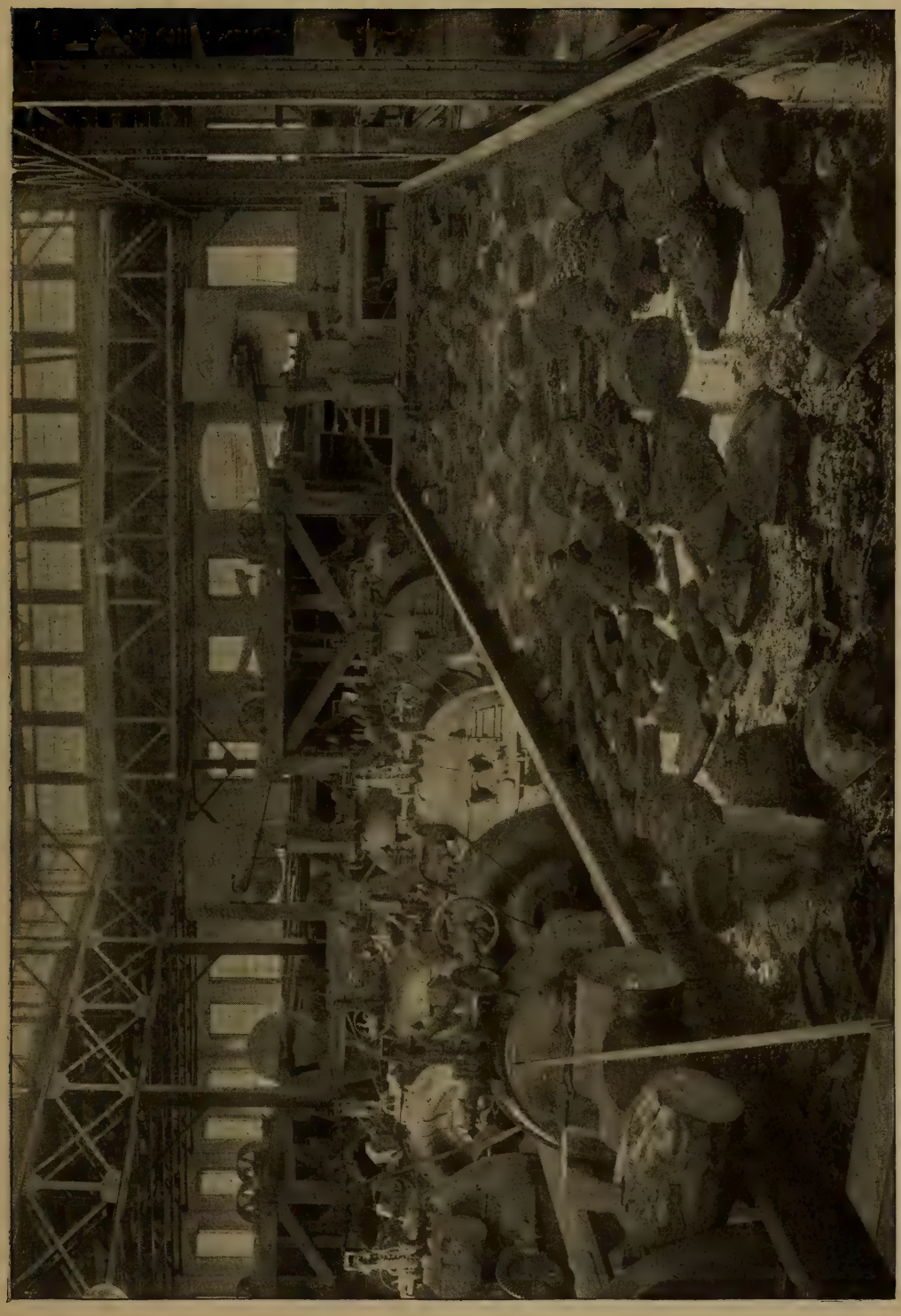
By Alton D. Adams

EVERYBODY reads a wooden newspaper, and without great forests to draw from the penny sheet would be impossible. Textile fibres, such as cotton and linen, are altogether insufficient in quantity to meet the demand for "first" and "latest" editions, and the prices of paper made with these materials would seriously cut down the circulation figures of the most enterprising dailies.

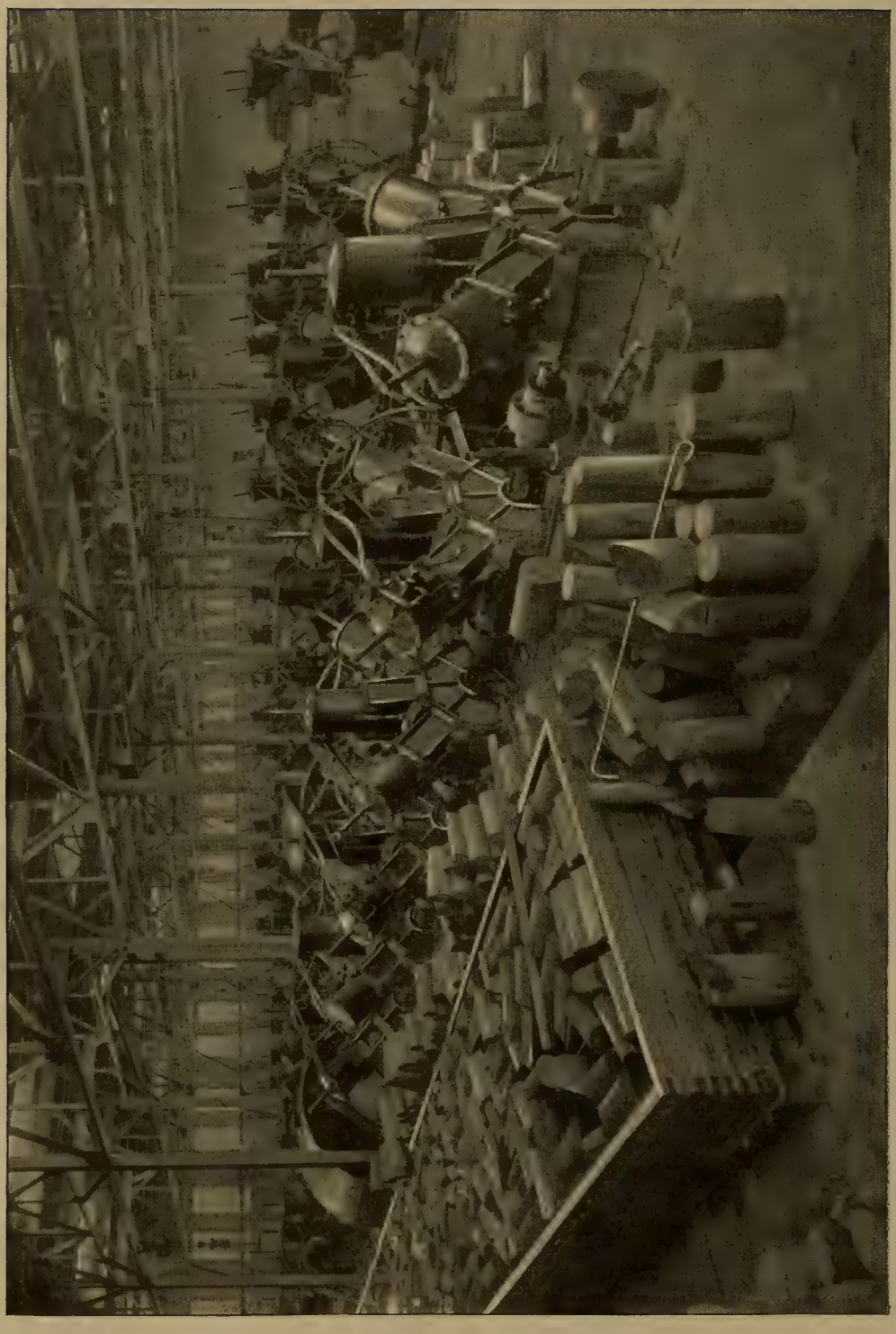
Production of paper from wood pulp has, therefore, greatly increased during recent years, and one of the latest efforts to meet the demand involves operations on so vast a scale that it is of especial interest. At the largest paper mill in the world 225 cords of wood are daily converted into 200 tons of first-class newspaper stock. This mill is located about seventy-five miles from Bangor, on the edge of the great wilderness of Northern Maine, U. S. A. The Great Northern Paper Company is the builder and owner of this plant, as it is also of the larger part of the town of Millinocket, which has grown up about it.

Less than two years ago the present site of the paper plant was a little strip of denuded forest area. Now five and one-half acres of roof cover the spot, and 700 workmen find employment under it. The location, close to the

SOME OF THE RAW MATERIAL

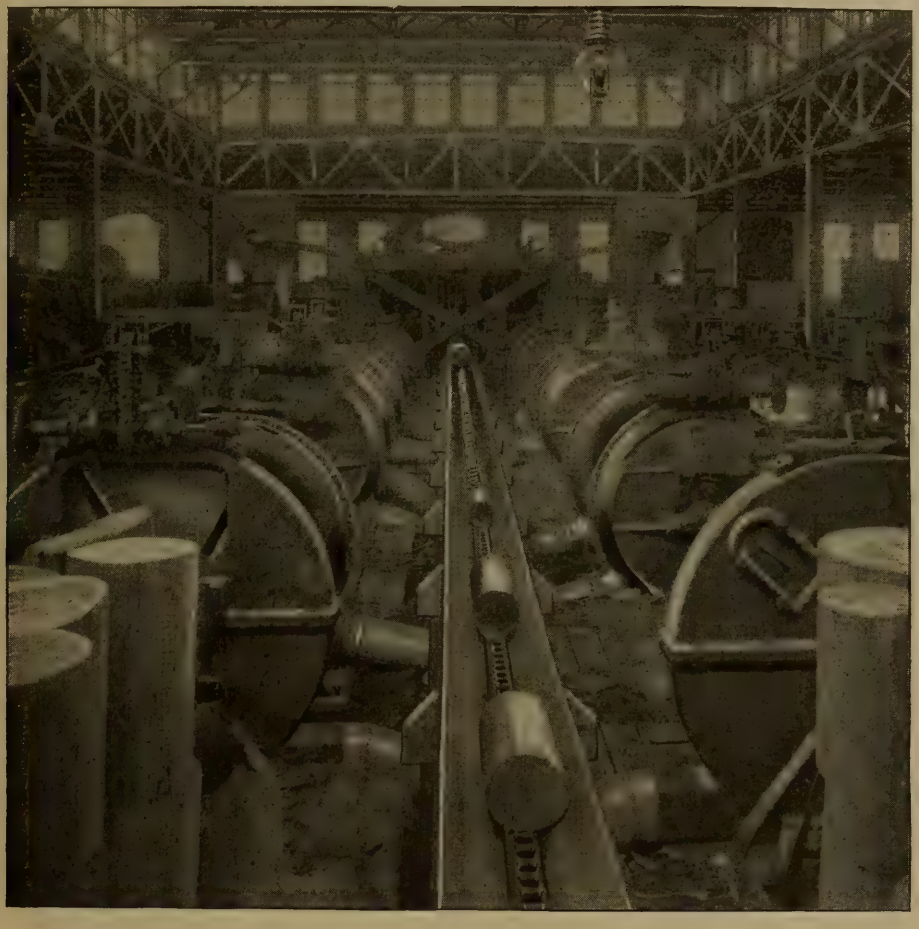


A VIEW OF THE BARKING MACHINES AND SAW MILL



GRINDING THE WOOD

vast forest area of Northern Maine, was selected, partly because of a large water power there available, and partly on account of its nearness to the timber supplies on which its operations depend. The mill of the Great Northern Paper Company is located on the bank of the Millinocket River, about one mile above the point where that stream flows into the west branch of the Penobscot River. The latter is a large stream, rising among the highlands of Eastern Maine, and flowing more than a hundred miles through the finest forest region of the State.



ANOTHER VIEW OF THE BARKING MACHINES AND LOG CONVEYOR

The paper mill derives its main supply of logs from it through a canal that connects the mill with the nearest point on the river. As 225 cords of wood are daily consumed to make paper, the yearly supply of logs for this purpose, on the basis of 310 working days, is 107,136,000 feet, board measure. This supply of lumber is mostly rafted down the river from its 2000 square miles of drainage area. Thus far the company has bought most of the logs necessary for its operations, but it is the owner of more than 250,000 acres of natural forest, to which it is proposed to apply scientific methods of timber culture, in order to provide an unfailing supply of wood for its future consumption. With this area of forest to draw from, the present consumption of wood by the company would require only 0.28 cord to be cut from each acre yearly.

Thus far only two-thirds of the ultimate capacity of paper-making machinery has been installed, so that about 338 cords of wood will ultimately be consumed per day, yielding 300 tons of paper as a product. Nearly all the logs used at the mill are of spruce, the variety of wood best adapted for the making of newspaper stock. A limit as to sizes in both directions is necessarily put on logs to be used at this

mill, those of less than 6 inches or more than 10 inches in diameter not being desirable. There is a loss of labour and of the use of machinery in handling logs of less than 6 inches diameter, while those above 10 inches must be split by hand, which also involves a loss, before they can be put into the grinding machine.

The amount of energy necessary to transform one and one-eighth cords of green spruce timber into one ton of dry, finished paper is relatively great. When the mill is in operation at full capacity it will require 30,200 horse-power, 27,400 horse-power being supplied by turbine water-wheels, and 2800 horse-power by steam-engines. As this expenditure of power produces 300 tons of paper daily, the work done is about 100 horse-power-days per ton of finished product, or, allowing ten working hours per day, 1000 horse-power-hours of work must be done to convert one and one-eighth cords of wood into paper.

There is a large shrinkage between the weight of the green spruce logs and that of the paper made from them. One cord of spruce just out of the water weighs about 3200 pounds, so that the one and one-eighth cords necessary to produce one ton of paper weigh 3600 pounds. A small part of this difference, 1600 pounds, between the weight of the one and one-eighth cords of wood and of the paper produced from it is waste in the form of bark and grit, but much the greater part is water which must be evaporated in the process of manufacture. To evaporate this water a large amount of heat is necessary, since each pound absorbs 966 heat units when passing into vapour. Making full allowances for shrinkage in the weight of the wood by losses of bark and waste, also for the small percentage of moisture that the finished paper contains, probably as much as 1200 pounds of water must be evaporated for each ton of paper made. At the maximum daily output of 300 tons of paper the water evaporated on this basis is, therefore, 360,000 pounds per day, or 36,000 pounds hourly, if ten hours make the working day.

Of the steam entering the paper machines where the drying is done probably not more than one-half does useful work in evaporating water from the paper stock. Steam in the paper machines is at low pressure, not far from ten pounds, and one pound of it on condensation yields, therefore, no more than enough heat to raise the temperature of one pound of water in the paper stock to 212 degrees and then evaporate it at atmospheric pressure. As, by the assumption, one half of the steam condensed does no work on the water in the paper stock, 720,000 pounds of steam per day, or 72,000 per hour, must be drawn from the boilers for the drying done in the paper machines. At the usual rating of thirty pounds of water evaporated from and at 212 degrees as a boiler horse-power, boilers of 2400 horse-power capacity should be provided for the work just considered. In addition, a large amount of steam is necessary in cold weather to heat the plant, also to cook a part of the wood pulp with acid in digesters, as will be mentioned later. All of these demands for steam, as well as some condensation in the engines that drive the paper machines, are provided for by 4800 horse-power capacity in boilers already installed, and provision has been made for further addition of 2900 horse-power. Steam used to drive the engines is exhausted into the heating system of the paper machines, where it has the same value, pound for pound, as steam directly form the boilers, through a reducing valve. Some of the steam entering the engine is condensed there, and thus does not reach the paper machines, but much the greater part loses little by passing through the engines.

Paper manufacture requires a relatively large investment of capital, and this is especially the case at Millinocket, where the most substantial construction has been followed in all of the buildings and the best machinery equipment adopted. The buildings cover a ground area of nearly six acres, and, with their equipment, have cost about $2,500,000 (£500,000). At the present rate of production fully 60,000 tons of paper

THE PULP ROLLERS

are turned out yearly, so that the investment in the plant is a little more than $40 (£8) for each ton of annual paper product. For the transportation of this quantity of paper a special track has been laid from the Bangor & Aroostook Railway, over a mile distant, to the paper plant. This track terminates at a large storehouse on the property of the paper company, where thousands of tons of paper are held ready for shipment.

Having noted the general conditions under which paper production takes place at Millinocket, it is next of interest to examine some of the processes more in detail. The spruce logs, floated from the river through the canal above mentioned, are received in a storage pond at one side of the paper plant, and are thence conveyed to the wood room, where they are cut by circular saws into lengths of 2 feet each. Taking the average diameter of these short logs at 8 inches each, 144 of them are necessary to make one cord, so that the 225 cords cut up per day yield 30,400 of the 2-foot pieces, or a total length of 60,800 feet. In a year of say, 300 working days the number of pieces is 9,120,000, and their combined length 3454 miles, or nearly that from New York to Liverpool.

The next step is to remove the bark from the short logs, and this is rapidly done by special machinery. This bark falls onto a constantly moving conveyor that delivers it at the boiler room where it is used for fuel. The supply of short, clean logs thus obtained is divided into two unequal parts, about one-third going to machines that reduce the wood to small chips, and two-thirds being conveyed to the grinding room. The wood chips next pass into revolving cylindrical screens where the grit on

them is removed, and thence to the digester room by a conveyor. The digesters are large cylindrical steel tanks, lined with brick, the joints being made with an acid-resisting compound. In these tanks the chips of wood are mixed with sulphuric acid and cooked for ten hours by admitting steam at about 100 pounds pressure. After this cooking process, the contents of the digesters, now called sulphite stock, are drawn into concrete pits and the acid is washed out.

The sulphite stock next passes into tanks whence it is pumped as desired onto screens, in order that any coarse particles may be removed. After this, the stock is distributed in a thick layer over felt, in machines where a large part of the water is removed from it by heavy pressure. From this last process it emerges in heavy sheets as a homogeneous, fibrous material, pinkish in colour, and its manufacture is then

IN THE BEATER ROOM

complete. The object of the sulphite stock is to hold the ground stock together in the finished product, just as stock made from rags does in some grades of book and writing paper.

The larger portion of the short logs, after arrival at the grinder room, is reduced to a fine pulp by the grinders. In each of these a special, hard stone revolves on a horizontal shaft, being completely surrounded by a heavy cast-iron casing. At three points about the periphery of each stone the casing is provided with cylindrical projections that extend in radial directions. Each projection is large enough to receive a log of wood, 10 inches in diameter and 2 feet long, one end of the log bearing on the face of the stone. After the openings in the case are closed, hydraulic pressure is applied, so as to force the ends of the short logs hard against the revolving stone, and the wood is thus ground to pulp. At present forty-eight of these grinders are in operation, so that one hundred and forty-four of the short logs are being ground at one time. As the present rate of paper production at the plant requires that about two-thirds of the daily supply of short logs, or about 2000, be ground up, it follows that 14 of the logs, or 28 feet of their length, must be ground in each receptacle per day. With ten hours for the working day, this rate of grinding corresponds to 2.8 feet per hour on each log.

This grinding requires a large ex-

A PORTION OF THE PAPER MACHINE ROOM

penditure of power. The forty-eight grinders now in operation consume 15,600 horse-power, each row of twelve grinders being direct-connected to the extended shaft of a turbine wheel of 3,900 horse-power. From this it appears that each grinder uses 325 horse-power, and each separate log 108 horse-power on an average. As 288 linear feet, or 144 of the short logs, with an average diameter of 8 inches, are required to make one cord, it seems, as 38 horse-power-hours are consumed per linear foot, that 10,844 horse-power-hours of energy are necessary to convert one cord of spruce wood to pulp.

From the grinders the pulp, after being mixed with water, is drawn into a series of wooden channels with little dams in each. The object of these dams is to catch the grit and small pieces of wood, which latter are removed by flushing at intervals, after the fine pulp has passed off. The fluid pulp next passes over two sets of screens in succession, the first being especially intended to remove slivers and the second, small bits of wood and grit.

Either clear water or white water is used to dilute the liquid pulp before it goes to the last set of screens, known as ground wood screens, and it has there reached a very fluid condition. The next step brings this highly fluid pulp to machines which remove a part of its water and pass the thickened mass into concrete storage tanks. The manufacture of this plain wood pulp is now complete, and it is ready to be mixed with the sulphite pulp previously described. White water mentioned above is the water separated from the ground wood pulp in the machines just mentioned, and this water goes thence to storage tanks, from which it is subsequently supplied to the pulp at the grinders or at a later stage of the manufacture.

Fibrous sheet sulphite pulp and the fluid ground wood pulp from storage tanks are next mixed in beating engines with some white water, the sheets of sulphite stock being torn up and rendered fluid with the other. This process is continued in chests to which the stock passes from the beating engines and where it is further mixed.

The stock is now ready to be converted into paper, and goes to the machine chest, where it is constantly agitated to prevent settling. From this chest the stock is pumped, as wanted, to the paper machines, where it arrives in a highly fluid condition. At one end of a paper machine the milk-like stock is uniformly distributed over a heavy blanket that passes through sets of hollow cast-iron rollers. Some of these

are heated by steam, and the pressure and heat together rapidly squeeze out or evaporate the water in the paper stock. Each paper machine is about 177 feet long and 18 feet wide. Successive sets of rollers, at right angles to the length of the machine, extend nearly from one end to the other, and each layer of paper stock passes between all the sets.

At first the rollers press only the water from the stock and blankets, not being heated, but a little later the stock reaches heated rollers and the process of evaporation begins. The moving blankets remain under the sheet of moving stock during a part of its course, to hold it together; but as the drying goes on, the sheet of stock grows stronger, and before the end is reached it is able to go alone. At the forward end of the paper machine the stock, delivered at the rear end in a liquid state, is wound, dry and tough, in standard rolls for shipment. The reduction of logs to paper is now complete.

A single sheet of good newspaper stock is about 0.003 inch thick, so that 4000 sheets, pressed together, are 1 foot high. The ordinary newspaper sheet of four pages measures 2 by 3 feet and contains 6 square feet, so that 666 of these sheets make 1 cubic foot. Allowing twenty-five pounds per cubic foot for the weight of this stock, the 200 short tons daily produced at Millinocket are equivalent to 16,000 cubic feet.

INDUSTRIAL CONSOLIDATION

ITS STIMULATING EFFECT ON AMERICA'S EXPORT TRADE

By Charles R. Flint

Mr. Flint's reputation as an industrial organiser is world-wide, and the influences which, in that capacity, he has helped to shape towards America's export trade expansion are reflected, to some extent, in his remarks below.—THE EDITOR.

THE stimulating effect of industrial consolidations upon the American export trade is shown by the very satisfactory increase in American exports of manufactured goods. This increase has been effected not alone through the more economic production made possible by industrial consolidation, but by the opportunity afforded, through consolidation, of introducing goods into other countries through the relatively cheap method of personal representation.

One of the causes of the slow growth of the export trade of the United States before 1895 was that the volume of export business in many important lines was too small to warrant any individual manufacturer going to the expense of sending an expert salesman to introduce his goods in foreign countries. A representative of a manufacturer who is not familiar with the merchandise offered is unable to meet the points raised by possible buyers, and his lack of knowledge retards introduction. Certain American manufacturers whose business had reached large proportions, determined that they could increase their export trade by sending out special representatives who thoroughly knew the goods they had for sale, and the competitive goods of foreign countries. Owing to the great volume of business of these manufacturers they were able to afford this expense. They arranged with commission houses who had prepared connections in foreign countries to attend to the financing, introduction, etc., of their representatives, so that their experts were able to concentrate their entire attention on pushing goods

without wasting time in searching into the status and character of prospective buyers. Under this scientific method of the use of experts the trade of such houses increased very rapidly and to important proportions, and in some cases they found their export trade more important than their domestic. These increases, too, were obtained without sacrifices in the shape of heavy reductions in prices.

Great numbers of the manufacturers of the United States, however, operated on too moderate a scale to be able to afford the expense of sending experts abroad. The expense of the operation was too large in proportion to their profits. They, therefore, found themselves forced to forego the advantages of obtaining an export trade in this way, and were compelled to use makeshift methods. As these manufacturers began to combine into larger aggregates, the expenditure for scientific foreign introduction of their merchandise was relatively small in proportion to capital and business to be done, and a large number of the great combinations have organised regular systems of making their goods known in foreign countries. As a rule, they have used the existing channels for financing and shipping, and have contented themselves with the profits upon merchandise without incurring the risk of granting credits in far-distant countries. This has been carried so far that the system of proper co-operation between the American manufacturer desiring export trade and the export merchant desiring to deal in the goods of a manufacturer may be said to have been thoroughly worked out, and merchant and manufacturer to-day operate as allies.

A manufacturer introduces his goods with the advice and assistance of the merchant. The merchant pays the manufacturer cash for the goods shipped, and is enabled to do this, as he is thoroughly familiar with the financial status in various countries and with the standing of buyers.

There are some organisations of great importance which, while in the open markets pursuing the method above explained, in the neutral markets, like Great Britain, Germany, etc., establish branches instead of operating through existing channels. This has been particularly true of manufacturers of steel, locomotives, railway equipment, and other large lines. It is also true of the manufacturers of many of the food products which the United States is now shipping in finished, instead of crude, form to European markets.

In certain lines of trade the American manufacturers who, by combination, have unified a great business and a great capital, have opened distributing agencies throughout foreign countries. The Standard Oil Company has followed this method more thoroughly than any other great organisation. Where intensity of competition or difficult local conditions have made it desirable, they have done their own business; wherever the competition has been less and they could advantageously utilise the export merchant they have done so.

One of the greatest sources of the growth of the export trade made practible through consolidation, has been the system of investigation into the position and facilities of foreign manufacturing competitors. Men of the highest order of ability are put in charge of this class of work, and any well-managed combination of manufacturers doing an export trade informs itself through every channel of the status and character of competitors in a way that could not be attempted by the individual manufacturer.

Another advantage to American export trade, or larger organisations of production, is the ability to deal with the question of over-sea transportation in a large way, with the result of important economies. In addition to the direct advantage of being able to lay down goods cheaper in foreign countries, there is the indirect advantage that these large shipments attract the attention of investors towards the field of ocean transportation, and by the ability of manufacturers to make large contracts American freight lines are estab-

lished and American shipyards are kept busy.

The American manufacturing organisation, from the head down to every labourer, is always discontented with the method of production and always searching for a better one. The American merchant is always looking towards improved systems of distribution, while foreign competitors reluctantly leave the old channels, and, in many cases, by their failure to act promptly on the lines that have been developed, give to their competitors a start in the race which can never be recovered.

Current Topics

To what extent the utilitarian spirit is growing in what one is disposed to consider as the dreamlands of the Far East is shown by the recently made statement that oil engines are now used in numbers in Palestine for pumping water from wells. The first attempt at introducing the engines there for that purpose is said to have been made about three years ago, by a German firm, the engines being small ones of 3 or 4 horse-power. At first no one would try them, but finally the agent of the firm in question volunteered in one case to set up an engine free of expense by way of experiment, and this little installation worked so well that it quickly led to the placing of several orders for more. Since then about sixty oil engines have been set up in different places, practically all for plantation work, about two-thirds of the engines having come from Germany and the others from British makers, the British engines, it is said, growing in favour on account of their greater simplicity of construction. This is an important point when it is considered that the engines are put in charge of native labourers during most of the time they are worked.

By-products as a source of profit have, for a long time, been an alluring subject. But while there have been undoubted advantages to individuals as well as to the public at large from the utilisation of what was at one time thrown to waste, there is an obverse side to the picture which enthusiastic writers on the subject are too apt to overlook altogether. In presenting this, recently, the London *Engineer* directed attention to the enormous expenditure which has been incurred by many persistent investigators in this recovery field before they or those who have profited by their researches have attained any real degree of success.

"A compilation of such statistics," says the *Engineer*, "would open the eyes of many of those who smell gold on the very name of by-product, and would make some of them pause in their career of attempted discovery. This may sound very like a condemnation of all research work and in praise of stagnation, but such is not the intention. What we wish to do is to throw out a warning note to those of limited capital; to exhort them to keep carefully in mind the whole circumstances before light-heartedly committing themselves to what may prove serious, if not disastrous, expenditure. For firms with ample monetary resource the case is different, and such firms deserve nothing but commendation for their efforts to solve industrial problems, even when the object is solely one of personal interest. This reference to object brings us to the remark that as all recovery processes have been undertaken with the primary object of personal advantage—leaving out of account the compulsory mitigation of nuisances—the market price of the by-products becomes the ruling factor in the situation. We have often come across recovery plant of one sort or another, and, finding it idle, inquired the cause. The invariable answer has been:—Oh! it does not pay to work it now. Further queries as to why this should be so have elicited the fact that the demand for the article recovered has fallen off, or perchance that it can be manufactured more cheaply and effectively at first hand. These are points that must always be reckoned with by those who, in the first blush of discovery, are perhaps too apt to fancy that future profits are assured to them.

"We cannot help thinking that too much is made in certain quarters of the prospective economic advantages to be derived by the community from a wholesale recovery of certain useful products which now run to waste. Let us instance sewage and smoke. We are continually being told that a national asset is being lost by allowing certain valuable bodies to be dissipated in the river, or the air, as the case may be. Actual values running into millions per annum have been calculated and published by enthusiasts with a view of bringing home to us the loss which our laxity entails. Such figures, however, must be received with caution because they are based on current prices, and not on prices which would rule were over-production to result. Reference has also often been made to the utilisation of town refuse for steam raising purposes, but it would not be difficult to enumerate cases where this has proved unsatisfactory, and where the use of ordinary coal with a known evaporative power has been had recourse to again. Nor can the progress which has been made in the manufacture of glass work from blast furnace slag be taken as indicative of the speedy annihilation of the unsightly slag mounds now in existence, or as a sure preventive against their increase in the future. Questions of much practical importance with regard to recovery processes are those of labour and depreciation of plant. Times have changed somewhat in the chemical trades; with a reduction in the selling prices has arisen increased cost of labour, and these factors, working simultaneously, have in many cases produced chaos."

In connection with the preceding paragraphs it is interesting to refer to a recent presidential address on the utilisation of white metal wastes, made before the Franklin Institute by Mr. Joseph Richards. Speaking particularly of the utilisation of tin clippings and galvanised iron scrap, Mr. Richards said that when he first took up the subject, many years ago, he found that large quantities of the above materials were daily carted away as waste. He found further that the average coating on scrap tin, as tin on tin plate, was 3 per cent.; that the iron if properly cleaned could be used in the nobbling furnace and in the puddling furnace;

that the use of galvanised iron was a necessary part of the process; and it looked so encouraging that he decided to build a plant to work on a commercial scale. He procured a half-dozen of the large lager beer casks used for storage, which are about 6 feet in diameter and 6 feet deep. After removing the heads, they were placed in the ground in a semicircle and a crane was rigged up that commanded all the tanks. In the first tank was hydrochloric acid; in the second, water; in the third, water with a little lime; in the fourth, water; and in the fifth, a solution of copper sulphate. The plan of work was to fill a large wooden cage that would hold loosely about 200 pounds of the clippings. This was swung on the crane and placed in No. 1 tank. In ten minutes' time the cage was raised and the clippings examined to see if the tin was dissolved. If so, the cage was then lifted out of the acid tank and another cage filled with clippings took its place. The cleaned scrap was washed in the water tank No. 2, lifted up and down to well wash it, and then immersed in the lime tank, No. 3. This neutralised all the residual acid that was left in the pores of the iron. The untinned and limed scrap was then moved to water tank No. 4 for a final washing, then plunged for a moment, just enough to submerge it, in the copper sulphate solution, and was then immediately removed. The object of this treatment was to form an exceedingly thin copper film on the iron to prevent the rusting of the clean iron, which is so sensitive when exposed to the air that it will almost instantly cover itself with rust. The cleaned scrap was compressed in a drop press into balls, and in this form was shipped to the iron works and worked into blooms for sheets, commanding a price of from $10 to $12 per ton. After the process had been continued for some time, all the acid in No. 1 tank would become neutralised and a solution of chloride of tin remained.

AT this point the process of tin cleaning stopped for awhile and the galvanised iron scrap was taken up for treatment. A cage loosely filled with this was immersed in the tank and when the zinc came in contact with the tin solution, the metallic zinc took the place of the tin, forming zinc chloride, while the tin was precipitated as metallic tin, in a finely divided state. This plant was worked successfully for some time, about 600 pounds of tin being recovered from 10 tons of scrap. The recovered iron commanded $10 per ton and the zinc chloride $20 per barrel, for disinfecting and other purposes. The works were finally closed because of the objectionable vapours that annoyed neighbours.

THE most notable event in marine engineering during the past month was the first arrival at New York of the new White Star Line steamship *Celtic*, the largest vessel now afloat, even if not the longest, measuring 700 feet in length, with a beam of 75 feet, and a displacement of 37,700 tons at a load draught of 36 feet 6 inches. How these dimensions compare with those of other well-known liners is shown in the tabulated statement below, but it may be noted incidentally that her displacement is 10,300 tons more than that of the *Great Eastern*, and more than double that of the heaviest warship afloat. Gross tonnage is used in the table, and the lengths given are over all.

Vessel.	Length. Ft.In.	Br'dth. Ft.In.	Depth. Ft.In.	Tons.
Great Eastern	691 0	82 8	48 2	18 915
Britannic	468 0	45 2	33 7	5,004
City of Rome	600 0	52 3	37 0	8,144
Etruria	520 0	57 3	38 2	7,718
Teutonic	582 0	57 8	39 2	9,984
Fuerst Bismarck	520 0	57 6	38 0	8,874
La Tourraine	540 0	56 0	34 6	9,209
Campania	620 0	65 0	43 0	12,950
Kaiser Wilhelm der Grosse	648 0	66 0	43 0	14,349
Oceanic	705 6	68 0	49 0	17,274
Deutschland	686 0	67 0	40 4	15,500
Celtic	700 0	75 0	49 0	20,880

It is interesting to add to this that the steamship *Great Western*,—the wonder of 1836,—was only 212 feet long, and her displacement at load draught was only 2300 tons. As the table shows, the *Celtic* is a few feet shorter than the *Oceanic*, but has 7 feet more beam, and is also the first vessel

THE WHITE STAR LINE STEAMER "CELTIC." THE LARGEST SHIP IN THE WORLD.

to go beyond the 20,000-ton mark. The engines are quadruple-expansion, driving twin-screws, and have cylinders 33, 47½, 68½, and 98 inches in diameter, while the stroke is 63 inches. Eight double-ended boilers, measuring 15 feet 9 inches by 19 feet 6 inches, furnish steam at 210 pounds pressure. The indicated horse-power of the engines is about 20,000. There are 64 men in the deck crew, while the engine-room and stokehold staff numbers 92. There are quarters for, altogether, 2859 passengers, the number of first-class passengers provided for being 347, and the number of second-class passengers, 160. The *Celtic* finished her maiden voyage from Liverpool to New York on August 5, having covered the 2890-mile course in a trifle over 8 days. Her builders are Messrs. Harland & Wolff, of Belfast, Ireland. The vessel emphasises anew the point which has been made on several previous occasions,—if coming ships are to be still larger, and, indeed, there is every promise of their being so, there will have to be a levelling-up in the practice of other branches of engineering. Docks and wharves will have to be built on a correspondingly greater scale, facilities for rapid loading and unloading will have to be increased, and harbours and their approaches will have to be deepened, and, in some cases, widened.

In a paper recently read before the American Water Works Association, Mr. H. F. J. Porter, of the Bethlehem Steel Company, tells that during a visit not long ago to a repair shop he stood by the manager of the concern watching the shrinking of a large steel coupling on to a shaft. The latter, which was hollow, had water running through it from a hose at one end to keep it cool. When the hot coupling was finally in position the hose was withdrawn and the water was played on the coupling, which was thereby neatly and firmly secured in place. While this work was being performed it was noticed that the machinery in the shop had slowed down, and on inquiry for the cause, the manager was informed that the engine-shaft had heated up and that the engineer was cooling it off. Adjourning to the engine-room, the engineer was seen turning the engine over slowly while he directed a stream of water through the shaft, which was hollow. The manager immediately

went up to the main bearing of the engine and put his hand on it. Its temperature evidently satisfied him that some more radical measures would have to be adopted than those which his engineer was pursuing, so, taking the hose from the latter, he turned the water on the bearing itself, and at once shrunk it on to the shaft, just as he had shrunk the coupling on to its shaft in the shop a few minutes before. The surprise which was depicted on his face when the engine stopped, was followed by an expression of anger, and then this narrow and humourless soul, feeling that the situation called for action on his part, expressed his sentiments in language both fluent and ornamental and promptly discharged the engineer. It was learned afterwards that the engine foundation had given away some time previously and that the engineer had repeatedly called the manager's attention to the urgency of necessary repairs.

ONE of the most interesting and remarkable of recent examples of freak locomotives was shown at the Paris Exhibition last year in the shape of the Thuile locomotive, of which an illustration is given on the opposite page. It formed the central feature in the magnificent display of Messrs. Schneider & Cie., of Creusot, France, and was built after the design of the late M. Thuile, or at any rate according to his system, being intended to haul "international" express trains, weighing 180 tons, at a speed of about 75 miles an hour on the level. To those items of information, displayed on the exhibit, was added the statement that the energy developed in the cylinders of the engine amounted to from 1800 to 2000 indicated horse-power. Dealing with this engine somewhat in detail in the London *Engineer*, Mr. Charles Rous-Marten, the well-known locomotive expert, not long ago remarked, among other things, that a melancholy interest was attached to the subject through the fact that M. Thuile lost his life through a mishap mainly due to his enthusiasm during a trial of his engine which led him to expose himself incautiously to a risk that proved fatal. Under such circumstances one feels considerable reluctance to criticise the design adversely. Yet candour compelled him to express the opinion that it is not one desirable to adopt in general use. Indeed, it would be difficult to imagine any conditions under which this very costly form of locomotive would be preferable to other types which could be built for little more than half the amount. There was no authentic information as to the sum which the Thuile engine actually cost to build, but Mr. Rous-Marten was convinced that, in normal circumstances at any rate, such an engine could not be turned out for much less than £6000, if even for that sum, and, moreover, there could not be discovered in the engine a proportionate working value. The engine and tender together run on no fewer than twenty-four wheels, of which only four are available for traction. The weight of the engine and tender in working order is very nearly 140 tons, and of this huge total less than 32 tons are available for adhesion, making an enormous proportion of dead weight in the total. In fact, considerably less than one-fourth of the engine's total weight is used for tractive purposes. All the remainder goes to carry the expensive means by which power is provided. This seems a fatal defect in the design,—the defect of wholly needless extravagance, alike in cost and in dead weight.

THE boiler is 28 feet 6 inches in total length and has a greatest diameter of 6 feet 7 inches, with a total heating surface of 3200 square feet, and a steam pressure of 213 pounds per square inch. Here, at all events, is stupendous boiler power. The two cylinders,—the engine is a non-compound,—are 20 inches in diameter with a piston stroke of 27½ inches. The four-coupled driving wheels are about 8 feet 2½ inches in diameter, by far the largest four-coupled wheels ever employed in locomotive

THE THUILE LOCOMOTIVE

practice. Thus, according to the accepted rule that if d represent the cylinder diameter, p the length of piston stroke, and D the diameter of the driving wheels, all in inches,

$$\frac{d^2 \times p}{D} = T$$

T being the tractive force in pounds for every pound of effective steam pressure in the cylinders. This would make the tractive force of the Thuile engine 111.6 pounds per pound of steam pressure on the pistons. But this is only the same virtually as that of a number of British engines which cost less than one-half as much as the Thuile locomotive. Clearly, then, the latter possesses no superiority in relative tractive force, notwithstanding its vast size and cost, and the question naturally arises,—What advantages does it possess to counterbalance its cost? Such advantages, however, have not been very evident thus far.

At this stage it may be convenient to mention some of the chief special details of this notable engine. The engine and tender run, as already stated, on no fewer than twenty-four wheels, this arrangement being absolutely unique and unprecedented. The engine itself has fourteen wheels, of which four, 8 feet 2½ inches in diameter, are coupled. The front part of the engine is carried on a four-wheeled bogie, the rear on one with six wheels. Thus, of the total weight of 80 tons, 31½ tons rest on the coupled wheels and 48½ on the two bogies—namely, 19¾ on the front and 28¾ on the hind bogie. The boiler is approximately oval in lateral section. Strictly speaking, the section of the upper half is of horseshoe shape, curving inward at the middle of the boiler, while the section of the lower half is elliptical. It is doutful whether this type of boiler will commend itself strongly to British engineers, but what may be deemed the inherent structural weakness of this shape appears to be corrected, so far as possible, by a strong system of staying. The tubes are of the Serve pattern, ribbed internally. The fire-box is of the Belpaire type, and has Tenbrink heating tubes. The steam distribution is effected by means of the Walschaert valve gear, which is so popular on the European Continent. Nickel steel of high quality is the metal chiefly used in the construction of the engine, which, it may be added, is fitted

with a dynamo turbine on the Laval system for the electric lighting of the train. There are two cabs, one in front for the driver; this is very spacious and convenient, well lighted, and has a wind-cutter, prow-shaped front; it is in communication by means of speaking tubes and bell signals with the rear cab, which is situated behind the fire-box, and is for the use of the fireman. The tender is of enormous size, and is designed to carry a vast supply of water and nearly seven tons of coal; the coal space is on an inclined plane, so as to facilitate the work of firing. It is understood that several of the French railways had the option of purchasing this curious and in many respects noteworthy locomotive, but were not disposed to take advantage of the opportunity.

DANGEROUS currents in overhead conductors for electric railways were made the subject of some very interesting trials some time ago by Professor H. W. Weber, of Zürich, Switzerland, two series of experiments being carried out upon his own person with the view of determining the limit of tension at which life was endangered. The investigation was prompted by the refusal of the authorities to sanction the use of anything above 500 volts in connection with the two electric railways known as the Stansstad Engelberg and the Zermatt-Gornergratt lines, which, however, have now been working for somewhat over two years with three-phase alternating current of 750 volts, conveyed through two overhead contact conductors, while the rails constitute the third wire. As noted in the "Foreign Abstracts" of the Proceedings of the Institution of Civil Engineers, the first series of Professor Weber's experiments was devised to meet the accident of a person laying hold of the two overhead wires at the same time with both hands bare, or the alternative of both conductors falling upon bare parts of his body. With wet hands, starting at 10 volts potential difference, a very slight trembling was felt in the muscles of the fingers; the measured strength of the current passing through the body from hand to hand was equal to 0.001 ampère. Increasing by 10 volts at a time, 40 volts paralysed fingers, hands, and arms instantaneously, producing almost unbearable pain, and in hardly any instance could the experimenter loose his hold of the wires again; after five seconds the pain became unendurable. At 50 volts there was likewise instantaneous paralysis of all the muscles in the same limbs, the trial became unbearable in two seconds at the outside, and the wires could not be let go without the greatest effort. With wet hands, therefore, no higher tension was tried. With dry hands, a slight tremor was occasioned of the muscles in fingers and hands at 50 volts, and the current strength was less than 0.0001 ampère. At 80 volts, fingers, hands, and arms were almost stiff, with severe pain in all parts, and only with great struggling could the wires be let go; the strength of the current was from 0.009 to 0.011 ampère. At 90 volts the hands were completely paralysed at the very instant of grasping the wires, which could not be let go again; the pain in hands and arms was so great as to make the experimenter shriek involuntarily, and the trial became unendurable in less than two seconds. On going back again to 80 volts, the difference was so great that the effect of this tension now seemed extraordinarily small in comparison with that of 90 volts. No higher tension was, therefore, tried. From this first series of experiments Professor Weber concluded that it is too dangerous to touch simultaneously both poles of an alternating-current circuit in which the potential difference exceeds 100 volts; it is impossible then to let go, and help must be forthcoming on the spot. Hence the prevalent notion that even 500 volts tension is not dangerous does not hold good; death is recorded where it did not exceed 240 volts.

THE second series of trials represented a person standing either upon the ground or upon the car, and touch-

ing one of the overhead wires. Here the feet are tolerably well insulated by the soles of the boots, and the nature of the ground affects the result. Standing on moist gravel, the experimenter could feel scarcely anything up to 800 volts potential difference, whether touching the wire lightly or grasping it tight; but at 2000 volts the wire produced a violent burning of the skin when lightly touched, and a strong tremor in the fingers when grasped tight. Standing on clay covered with moist coal-dust, he could feel scarcely anything below 200 volts; but at 1000 volts the skin was burnt as if by fire on lightly touching the wire, and on grasping it tight the effects upon fingers, hand, arm, and feet were unbearable in less than two seconds, and the wire was with difficulty let go. On grasping it tight at 1300 volts, fingers, hand, and arm were completely paralysed, and it could not be let go. Hence the tension should not exceed 1000 volts. While, therefore, the potential difference begins to grow dangerous as it rises above 200 volts, Professor Weber concluded that there is no need to be afraid of using the higher tensions, between 500 and 1000 volts, which are so much more advantageous; for there is extremely little likelihood of passengers or others ever happening to touch both wires at once. The only persons exposed to this risk are the men employed on the wiring, who, as a rule, are trained to understand the danger and to guard against it. The consequence of the foregoing experiments was the sanction of 750 volts for the working of the two railways mentioned at the outset.

An interesting little story was told some time ago of someone in the practically waterless parts of Western America, where there is barely sufficient water for drinking purposes, who proposed to drive, or was actually driving, a number of arastras by sand, the latter turning a large overshot wheel, taking the place of water. The intention was at first to run the arastras by means of a large windmill, but the uncertainty of this power finally led to the adoption of the plan mentioned. A windmill still was to form part of the scheme, but it was to run a conveyor to carry the sand up to a large elevated tank. From this the sand was to be eventually allowed to run out upon the overshot wheel, causing it to revolve just as it would under the weight of a stream of water, and the sand tank had sufficient storage capacity to insure continuous running of the plant. There the tale ended, though a few more particulars of the right kind would have given it a more likely colouring.

The principle of the so-called water curtain which was proposed quite a number of years ago for fire protection in theatres, being intended to cut off the auditorium from the stage, has of late been applied in many instances for ordinary building protection, the arrangement being such as to cause water to fall in a sheet—either all around a structure or down one side or several sides of it. In the case of one large public building, of which particulars have recently been given, a 7-inch steel water main is laid around the top of the structure, upon the broad stone table formed by the top of the coping. This pipe is connected with force pumps in the basement, and, through perforations properly arranged, insures the introduction of a substantial sheet of water from cornice to pavement, around the whole or any imperiled portion of the building. The arrangement of the system of piping is said to be such as to permit of operating in prescribed sections, and additional relays of smaller pipe are placed in position above windows and doors in order to complete the curtaining of those points in the most serviceable manner, should the curtain in the main be broken by wind impinging against the building or through some other cause.

On the subject of turbine engines and their adoption in British warships,

Mr. Arnold-Foster, replying to a question addressed to him in the House of Commons, recently said:—"No conclusion has yet been reached as to the adoption of the turbine system of propulsion for vessels of his Majesty's fleet. Experience with the recently wrecked *Viper* had shown that higher speed could be realised with her turbo-motors than could be obtained in a destroyer of similar dimensions and form fitted with ordinary engines. Vibration was practically avoided. It does not appear correct to say that the turbo-motor engines necessarily occupy less space than the ordinary reciprocating engines, but they require less vertical height, and therefore can be more easily kept below the water line—an undoubted advantage. The total engine-room and boiler-room complement of the *Viper* was larger than that required in the 30-knot destroyers fitted with the ordinary engines, but the horse-power developed at her maximum speed was greatly in excess in the former. Proposals with outline designs for fitting turbo-motors in third-class cruisers and new types of destroyers are now under consideration. No decision has been reached respecting vessels included in this year's programme."

THE most economical results thus far obtained with superheated steam have been secured with compound engines. The use of triple-expansion engines with such steam is thought by many designers to be inadvisable, because of increased initial expense, increased friction, increased oil consumption, care and complication, and inadaptation to fluctuating loads, to say nothing of jackets, reheaters, and space requirements. In a recent paper before the American Society of Mechanical Engineers, Mr. George A. Hutchinson cited the case of a triple-expansion engine installed at the factory of Ed. Vaucher and Cie, of Mulhausen, which was so arranged that it could be operated as a triple, with superheated steam in the high pressure cylinder, or as a componnd engine with a reheating receiver, and using superheated steam, therefore, in both cylinders. When operated as a compound machine, there was a gain of 10.5 per cent. over the steam consumption, and 6 per cent. over the coal consumption, of the engine when operated as a triple, and a reduction in the indicated work from 746.5 horse-power to 727.2 horse-power, although the load carried under both conditions was kept the same.

CHARLES R. FLINT

The "Father of Trusts"

A BIOGRAPHICAL SKETCH

By W. D. Walker

IT would be difficult, in the small space here at command, to give any detailed sketch of Mr. Flint. The closing years of the nineteenth century will be referrred to in the future as the period when the movement toward industrial consolidation in the United States reached its zenith, and when the history of that movement shall be written the name of Charles R. Flint, a pioneer in the movement and one of the most successful organisers of his time, will be a predominating feature.

He was born at Thomaston, Maine, in 1850, and was graduated from the Polytechnic Institute at Brooklyn, N. Y., in 1868. In 1871 he was partner

in the firm of Gilchrist, Flint & Co., and from 1872 to 1875 he was a partner in the firms of W. R. Grace & Co., of New York, Grace & Co., of Chile, and J. W. Grace & Co., of San Francisco. He organised, in 1876, the firm of Grace Brothers & Co., of Callao, Peru, remaining on the West Coast of South America for nearly a year. In 1887 he was Consul of Chile at New York, and, during the absence of the chargé d'affaires, was in charge of the archives and correspondence of the Chilian Legation. He has also in recent years been consul-general in the United States of the republics of Nicaragua and Costa Rica.

It was in 1878 that Mr. Flint foresaw that the inevitable trend of business was towards consolidation. In that year he organised a consolidation of several lumber companies under the name of the Export Lumber Company, Limited. This company has yards at Ottawa, Montreal, Boston, Portland, Me., New York (Greenpoint), carries stocks of lumber in West Virginia, South Carolina, the Adirondacks, New Hampshire and Michigan, and handles over 200,000,000 feet of lumber per year. It is one of the most successful lumber concerns in the United States. In 1881 Mr. Flint took up the crude rubber industry and consolidated the four leading factors in that business. Three years later he visited Brazil and spent some time on the Amazon, acquiring a thorough knowledge of the details of the rubber business and establishing houses there. Since that time, organisations with which Mr. Flint has been identified have handled crude rubber to the value of over $250,000,000, his crude rubber interests now being in The Crude Rubber Company, of New York, which has branches in the rubber producing markets.

In 1885 he became a partner in the house of Flint & Co., composed of his father, Benjamin, his brother, W. B., and himself, devoting some years to the development of a general export and import commission business. In 1891 he organised the United States Rubber Co., which has a capital of $47,191,500. In 1892 he brought about a union of five companies manufacturing belting, packing, hose, clothing, and druggists' sundries, under the title of the Mechanical Rubber Company. Subsequently this became a part of the Rubber Goods Manufacturing Co. which Mr Flint organised, this latter company taking over the businesses of the principal manufacturers of belting, packing, hose, mats, interlocking tiling, tires for bicycles, carriages and automobiles.

In 1895 Mr Flint consolidated the export and import business of his firm with that of The Coombs, Crosby & Eddy Co., under the style of Flint, Eddy & Co. This concern was, in the summer of 1900, further augmented by consolidation with the American Trading Company, under the name of Flint, Eddy and American Trading Company, with a capital of $4,000,000. This concern does an export business with every country in the world, and is the largest buyer in the United States of manufactured goods for export. Among the other consolidations which Mr. Flint has brought about, or with which he has been identified, are the American Chicle Company, capital $9,000,000; the Sloss Sheffield Steel and Iron Company, with a capital of $18,200,000; the American Caramel Company, with a capital of $2,600,000; the U. S. Bobbin and Shuttle Company, with a capital of $2,300,000; the American Sewer-Pipe Company, with a capital of $12,500,000, and the National Starch Company, with a capital of $13,500,000. Mr. Flint has also organised the Atlantic Coast Lumber Company, with headquarters and mills at Georgetown, South Carolina, with a capacity of 500,000 feet per day, and which has been alluded to as the "Carnegie plant of the lumber business." In order to advantageously market the product of this company, Mr. Flint organised the Atlantic Coast Steamship Company, which owns four new steamers built specially for the lumber carrying trade and plying between Georgetown and northern coast ports. Mr. Flint was a member of the International Con-

ference of American Republics in 1889-1890, representing the United States on the Banking-Committee, and was a member of the Committee on Customs Regulations; in 1891 he assisted in the negotiation of the Reciprocity Treaty with Brazil. In 1893 he fitted out a fleet of war vessels for Brazil, which arrived there in time to strengthen the republic and defeat the monarchists in their attempt to re-establish an empire.

In 1896 he established the Flint & Co. Pacific Coast Clipper Line, between New York and San Francisco. Four years later this line sold their entire fleet of clipper ships, and the American-Hawaiian Steamship Company was organised, which has in service and building seven large steamers varying from 1100 tons dead weight capacity to 6500 tons. In 1897 Mr. Flint was chairman of the reorganisation committee which consolidated the street railroads of Syracuse, under the name of Syracuse Rapid Transit Railway Company. In 1898 Mr. Flint acted as confidential agent for the United States Government in negotiations for war vessels and munitions of war in the war with Spain.

Mr. Flint, notwithstanding his large business interests, is a keen sportsman. He is a member of a number of shooting and fishing clubs, and religiously spends one day each week either fishing or shooting. He was a member of the syndicate which built and raced the *Vigilant*, and which successfully defended the America's cup against the *Valkyrie*. He is now building the *Arrow*, which is known as a torpedo-yacht, expected to attain a speed of 45 miles an hour, and capable of being transformed into a torpedo-boat within three days.

PHOTO BY GUTEKUNST, PHILADELPHIA

John H. Converse

PRESIDENT OF THE BALDWIN LOCOMOTIVE WORKS, PHILADELPHIA

SEE PAGE 519

CASSIER'S MAGAZINE

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ELECTRIC POWER AT JAJCE, IN BOSNIA

By John B. C. Kershaw

THE HEAD RACE, SHOWING ONE THE FIFTEEN TUNNELS ALONG THE LINE

JAJCE, the locality of one of the largest and most interesting water-power developments in southeastern Europe, is a small, fortified town in the province of Travnik, Bosnia. Before the advent of the hydraulic and electrical engineer the population of the town was less than 4000 persons, and it does not appear to have possessed any staple industry. The work in connection with the development of 9200 H. P. at this spot has, of course, added largely to the floating population of the town and district, and when the period of experiment is over and the whole of this power is utilised in manufactures for which a demand exists in the more immediate neighbourhood, the town of Jajce is likely to become a manufacturing and industrial centre of considerable importance.

The water supply for the power station at Jajce is drawn from the River Pliva at a point between the larger and smaller Jezero lakes. The Pliva is a wild mountain stream, draining a territory estimated to cover 288 square miles. In the course of its 22-mile flow it receives many tributary streams, the most important of these being the River Janij.

It is considered probable that the Pliva is fed also by many subterranean springs, as these are common in the neighbourhood, and the source of the Pliva itself is such a spring at the foot of a steep mountain escarpment. Towards the end of its course the Pliva widens out into the larger "Jezero-See" close to the small township of

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THE SLUICE GATES AT THE OUTLET OF GREAT JEZERO LAKE

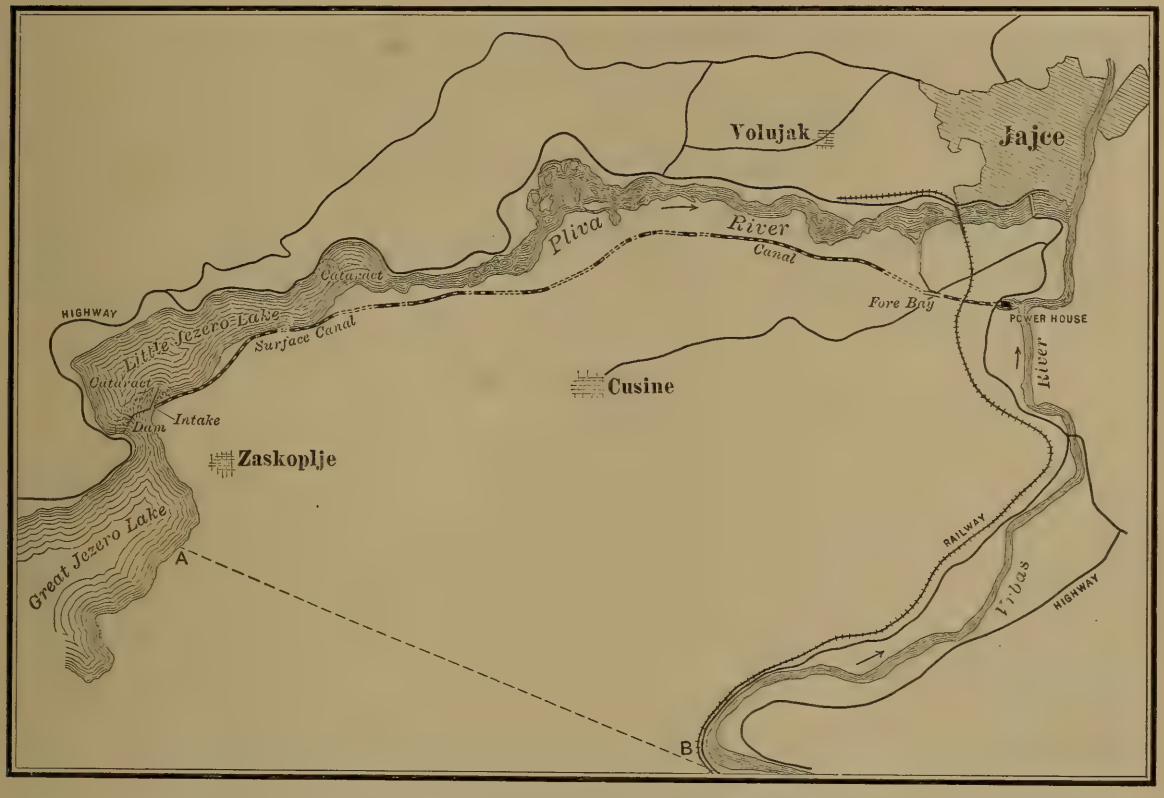
Jezero. This lake is about one and three-quarter miles long by one-third of a mile broad, and from it the water falls 21 feet over a natural escarpment, covered with vegetable growth, into the smaller "Jezero-See," which has a length of 1050 yards and a breadth of about 340 yards at its widest point. The outlet from the smaller lake takes place by a series of cascades and falls of 28 feet, and after a short, turbulent stretch of one and three-quarter miles, the Pliva finally ends its course by plunging over a bluff 82 feet high into the River Vrbas. This latter river runs at right angles to the final course of the Pliva, through the small town of Jajce. The difference in level between the surface of the upper Jezero lake and the water of the Vrbas River is 129 feet. The flow of water in the Pliva at the point where it falls into Vrbas varies between 10,590 and 494 cubic feet per second in the wet and dry seasons of the year, respectively.

French and Swiss engineers had discussed the question of power development at this spot up to the year 1896 without any practical result, but in that year the German firm of Messrs. Schuckert & Co., of Nürnberg, took the matter in hand, and planned the erection of a power station with a capacity of 9000 H. P. The original plan was for the construction of an underground supply tunnel between a point on the larger "Jezero-See" and the nearest point on the banks of the Vrbas River (along the dotted line *A B* in the map opposite); but on investigation the difficulties attending the carrying out of this scheme proved to be too great to render it practicable. The plan finally adopted involved the construction of a canal from the outlet of the larger "Jezero-See" along the course of the river valley to a point about 330 yards above the fall of the Pliva into the Vrbas, and the construction of two pipe lines for carrying the water from this supply canal down the face of the bluff into the power house. The map of the district, reproduced opposite, shows the course followed in the construction of this canal and the points where the natural configuration of the ground necessitated tunnelling.

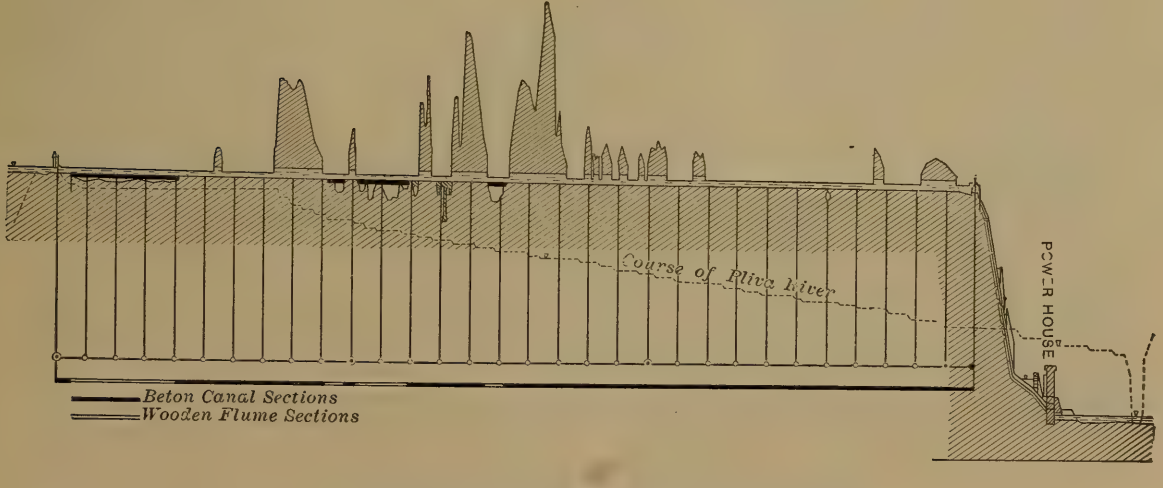
A new company, the "Bosnische Elektricitäts Aktiengesellschaft," was formed in 1897 to carry out the scheme

in conjunction with the Nürnberg firm, and work was actually commenced on November 1, 1897. The excavations necessary in connection with the enterprise involved the removal of 35,300,000 cubic feet of material, while 400 tons of Portland cement were used for the stone work of the dam, weir, and canal. The whole work, including the erection and equipment of the power house, was completed in seventeen months,—a splendid time record for a power station of this magnitude. The turbines, pipelines, and ironwork of the sluice gates were supplied by Messrs. Ganz & Co., of Buda-Pesth, while Messrs. Schuckert & Co., of Nürnberg, supplied all the electrical equipment of the power house and the furnaces for the carbide works in which the power is used.

The point where the intake of the supply canal is located, as already noted, is at the escarpment which separates the two Jezero lakes. At this spot a concrete dam was built, the storage capacity of the larger "Jezero-See" being



THE GENERAL SCHEME OF THE JAJCE INSTALLATION



A PROFILE MAP OF THE WATER POWER CANAL

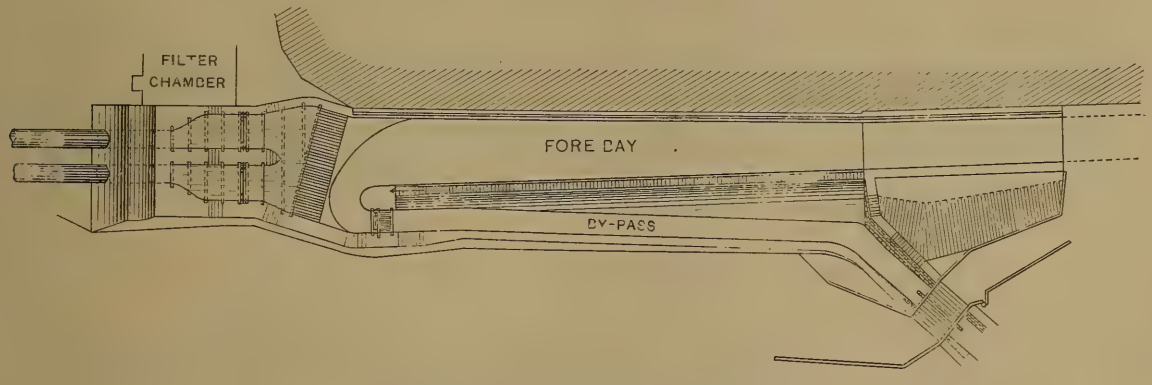
THE DAM AT THE OUTLET OF THE UPPER LAKE

THE FOREBAY NEAR THE POWER HOUSE

thus increased to 15,000,000 cubic feet. At exceptional periods this storage capacity can be still further increased by the insertion of boards in iron stanchions, these latter having been fixed at intervals of 7 feet, for this special purpose, in the crown of the cement dam. At the eastern corner the dam is provided with two sluice gates,—one for the discharge of mud and gravel accumulations into the smaller lake and the other for regulating the supply of water to the canal.

Provision is made for the collection and removal of sand, gravel, and drift-wood at this point, and a supply of water is also provided for driving two mills situated near to the intake of the canal. The sluice gates are of oak and are tunnelled, there being fifteen such tunnel sections along the whole course. The breadth of the canal at the water level is 13 feet, and the depth of water carried is 5 feet. A fall of 1 foot per 1000 feet has been allowed. The head of water at the power house is, therefore, about 110 feet.

The canal ends in a forebay from which issue two penstocks running down to the power house. These penstocks run into separate divisions of the forebay, and each of these is provided with a sluice gate for cutting off the supply of water from the canal. Grids are provided for holding back leaves and other foreign matter which have fallen into the water during the two-mile passage along the canal. Surplus water



AT THE POWER HOUSE END OF THE CANAL

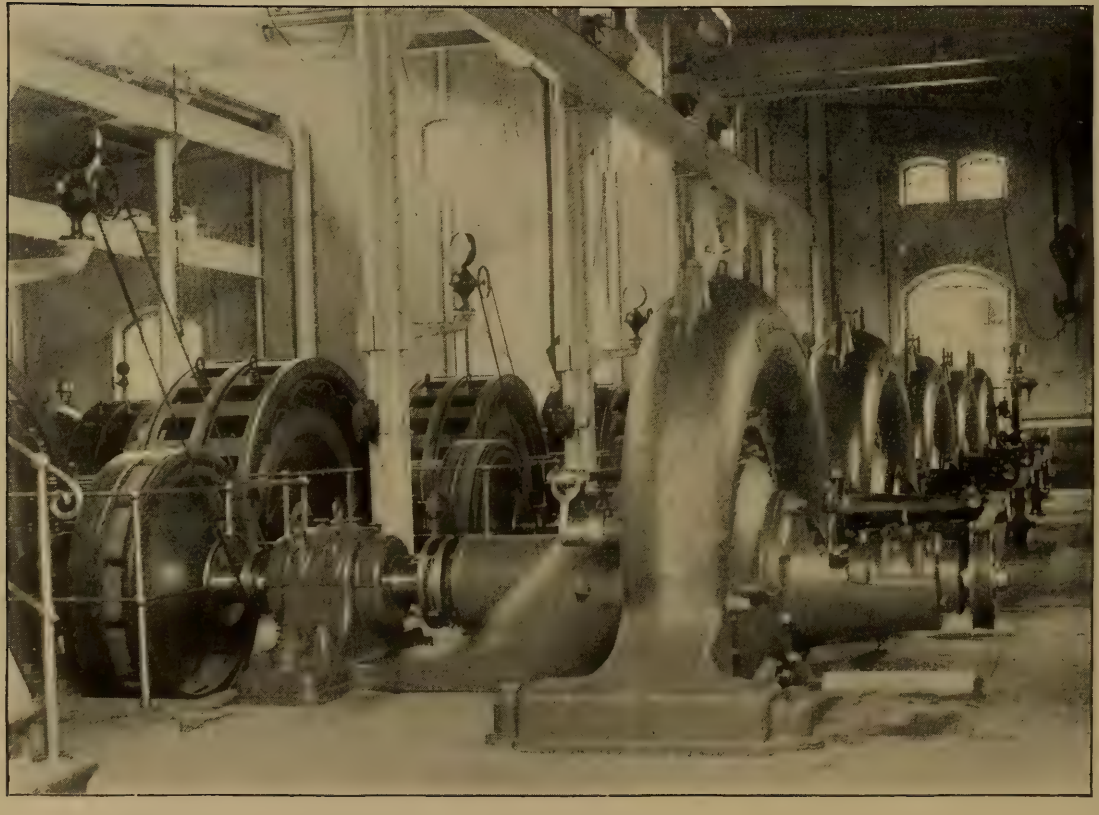
can be operated by one man, who is provided with a small house and is constantly in attendance at this spot. A telephone line runs from there to the power station at Jajce, and an automatic signal apparatus is also installed to warn the engineers on duty at the power house of any sudden and unexpected rise in the water level.

The canal follows fairly closely the course of the Pliva, and is, in part, an open channel, and, in part, a tunnel. When possible, cement was used in the construction of the open sections of the canal, but along some portions of the line a wooden flume structure had to be carried on trestle work. The total length of flume and canal, between the intake at the lake and the forebay at the power house, is 3382 yards, of which total 1031 yards, or nearly one-third, is led off through a by-pass provided with its own sluice gate, and when necessary the whole length of the supply canal can be emptied through this outlet.

The diagram on this page shows the arrangement of the forebay and sluice gates for regulating the supply to the two pipe lines and the outlet through the by-pass. An electro-magnetic device is provided at this point, whereby if either pipe line should burst at any point the controlling gate would be automatically closed. The pipe lines are made of Siemens-Martin steel plates, and are each 5.24 feet in diameter. As the length is considerably over 100 feet, a slip-joint is provided about the middle of each pipe in order to allow for expansion and contraction.

The power house contains two rows

THE POWER HOUSE

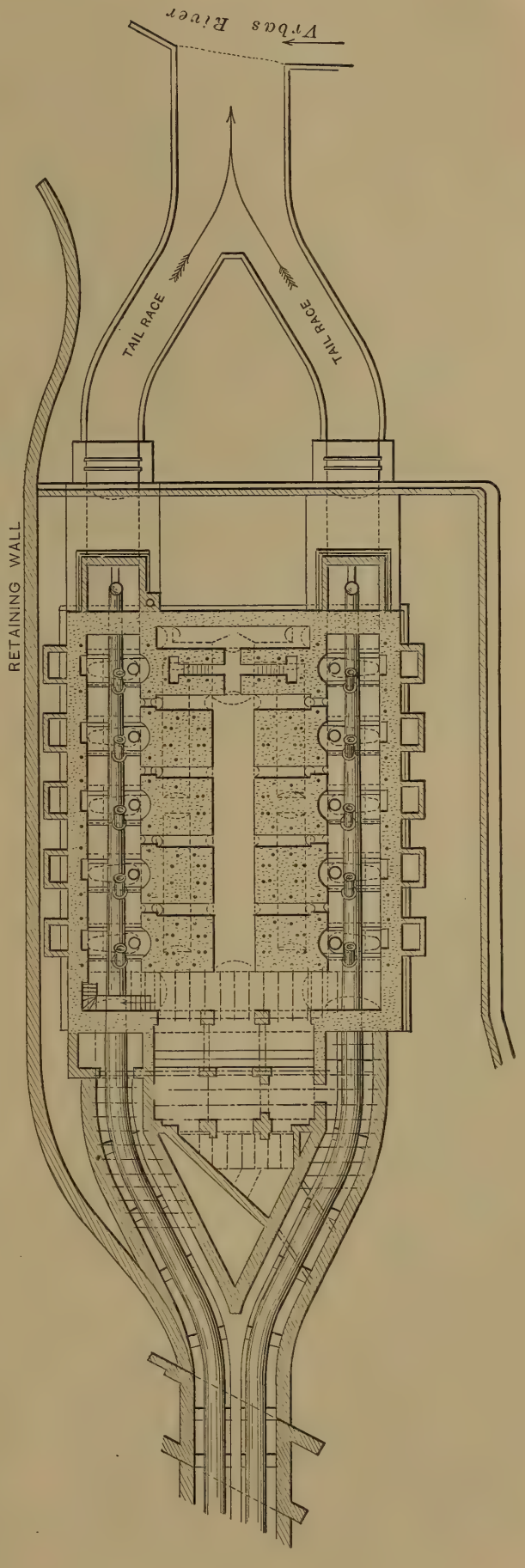


A VIEW OF THE INTERIOR

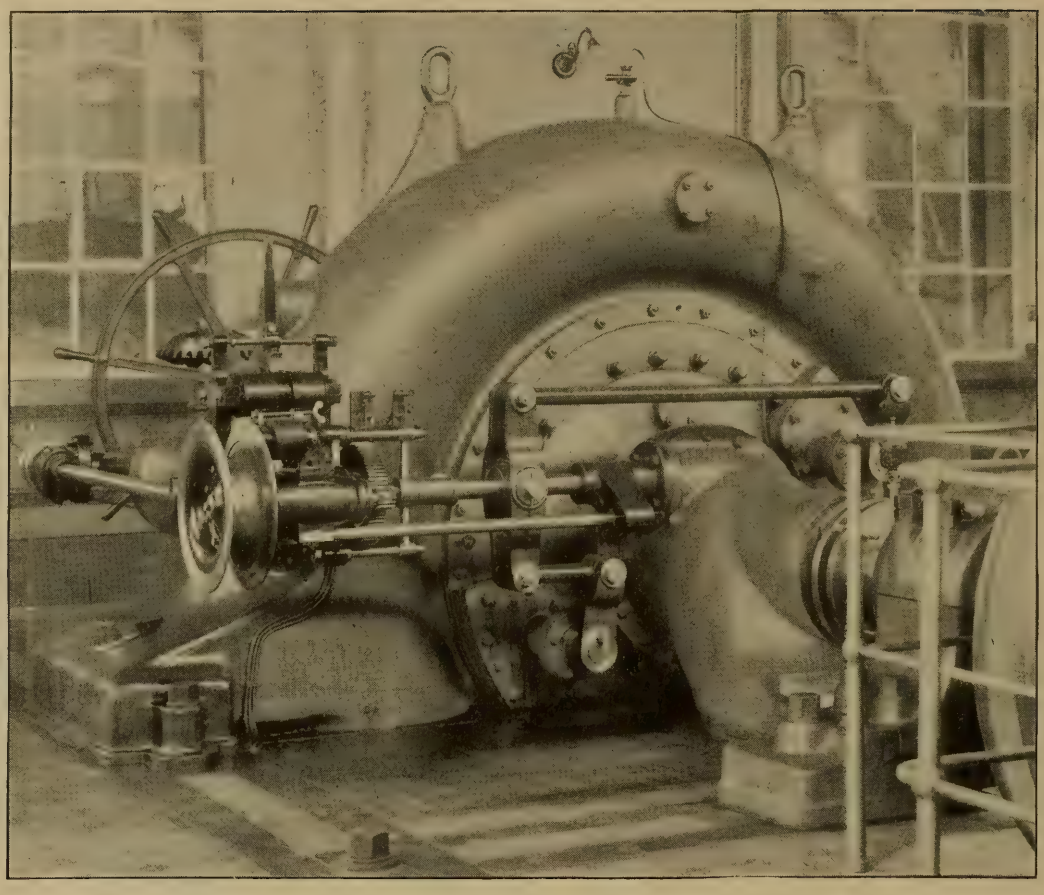
of five turbines, each row being fed by one of the pipe lines. A vertical feed-pipe provided with a hand-regulated throttle valve supplies water to each turbine, and each supply pipe ends in an air chamber, in order to minimise water hammer in the pipes. The turbines are of the reaction Francis type with horizontal axes. Eight of the ten turbines, when running at 300 revolutions per minute, yield 1000 H. P. each, while the remaining two are of 632 H. P. each. Each of the larger turbines is direct-coupled, by a flexible coupling, to a triphase Schuckert generator.

The arrangement provided for governing the 1000 H. P. turbines is of especial interest. When running triphase generators in parallel, it is absolutely necessary to strictly govern the power applied at the shaft of the generator, if each is to yield current in accordance with its size and capacity. The ordinary type of centrifugal-ball governor is useless to effect the desired end, since the principle of this governor is based on a variable speed of revolution, while the speed of generators coupled in parallel is determined by one generator for the whole set. It is, therefore, necessary when an alteration in the load of a triphase generator coupled in parallel is required, for the engineer in charge to alter the weights of the ordinary centrifugal ball governor. In large installations this method has drawbacks, and it has been considered better in the present case to dispense altogether with automatic governors. In place of these a method of hand governing has been worked out, the mechanism being controlled from the power house switchboard where all load variations can at once be noticed.

The diagram given on page 451 illustrates the arrangement in use. A strap from the shaft of each turbine drives a parallel running spindle *W* ending in a conical



FOUNDATION PLAN OF THE POWER HOUSE



ONE OF THE TURBINES SHOWING THE GOVERNING MECHANISM

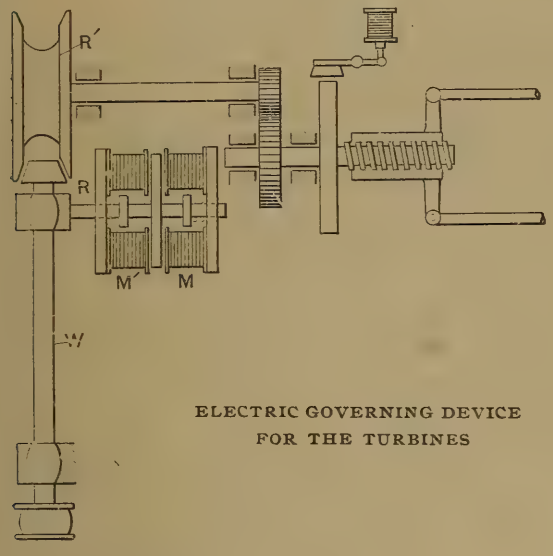
friction wheel *R*. The spindle *W* is slightly movable at right angles to its length. If either of the two electro-magnets *M* or *M'* should be excited by the passage of an electric current controlled by the touch of a key by the operator at the switchboard, the armature will be attracted, and the conical friction wheel *R* will be drawn against the side of the channelled wheel *R'* and the latter will be set in motion. This movement of the wheel *R'* is transferred by toothed-wheel gearing and a screw to levers acting on the throttle valve on the supply pipe of the turbine. The movements of the armatures of the two electro-magnets *M* and *M'* take place in opposite directions, so that the effect produced by sending a current through *M'* is reversed on exciting *M*.

The two 632-H. P. turbines previously mentioned are direct-coupled to two continuous-current generators, also of Schuckert build. The governing mechanism for these is of the hydraulic type. The waste water canals of the two rows of turbines unite outside the power house, as shown on page 449.

The power from the station is used in the manufacture of calcium carbide, alkalies, and chlorine in neighbouring works, also built by the Schuckert Company. Each of the alternating generators delivers 3000 ampères at 350 volts, and this current is used to operate three carbide furnaces. The two direct-current generators operated by the 632-H. P. turbines deliver, together, 7200 ampères at 120 volts. This current is used in the adjoining works for the production of alkalies and chlorine. The current from the alternating generators is carried to the carbide works by ninety-six bare copper cables, each cable being made up of nineteen ¼-inch wires, and the total sectional area of each cable is thus 0.93 square inch.

The machinery of the power station was first operated at the end of March, 1899, and since that date it has been running, with occasional stoppages, for

the supply of current to the neighbouring carbide and alkali works. Two thousand horse-power were utilised at first for carbide manufacture, and this



ELECTRIC GOVERNING DEVICE FOR THE TURBINES

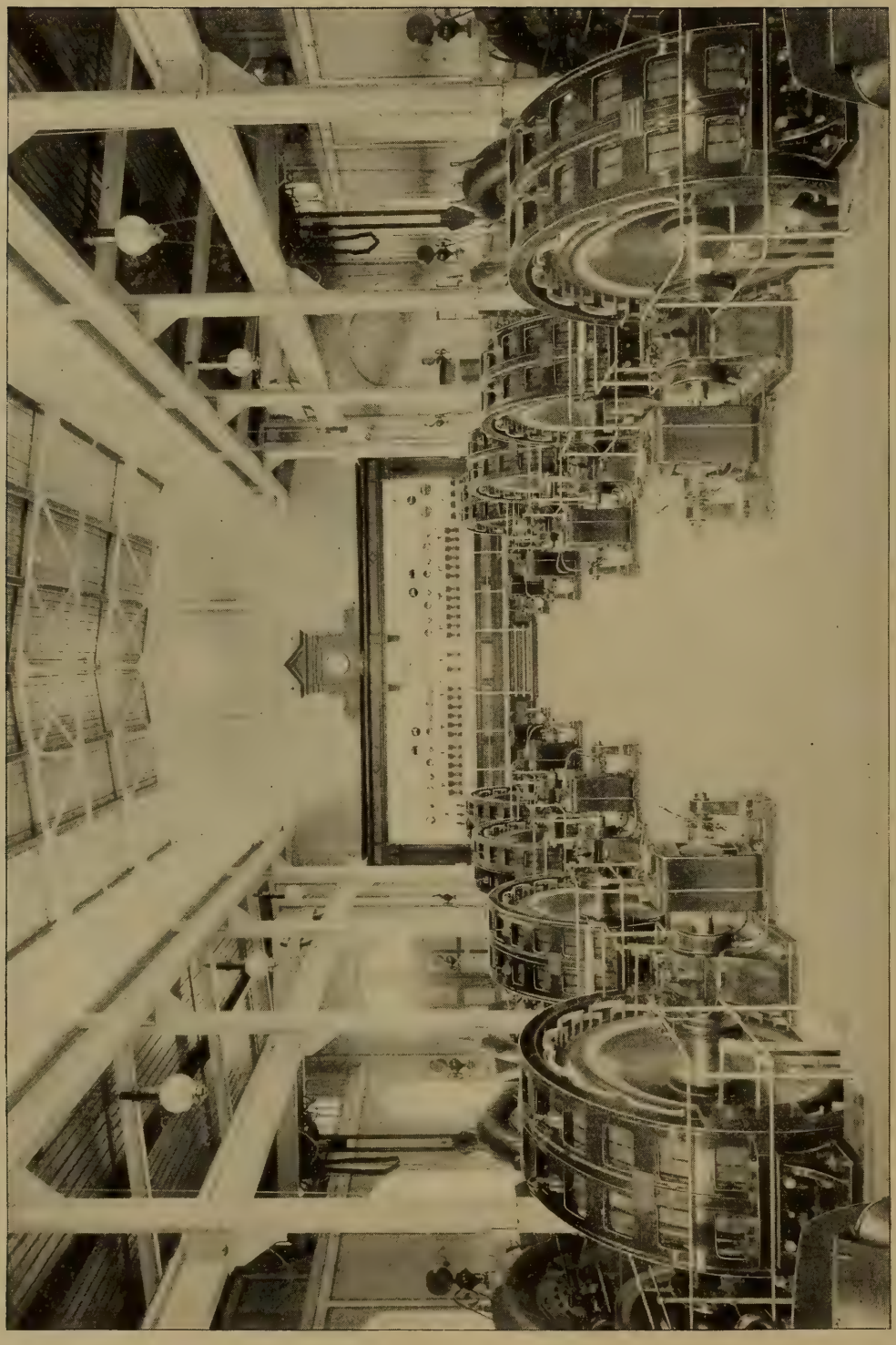
was gradually increased; but the fall in the value of carbide that took place in 1900 naturally affected the works, and at the present time only a small portion of the total power available is being used for carbide making.

The establishment at Jajce is another example of the advances made possible by the alliance between hydraulic and electric engineers. It has been customary to assume that all the large power developments of recent years are due to the possibility of transmitting the power by high-tension electric current to some distant point. But this explanation of recent progress touches upon only one of the three facts that have contributed to the success of the various large hydraulic electric power stations now operating in Europe and America.

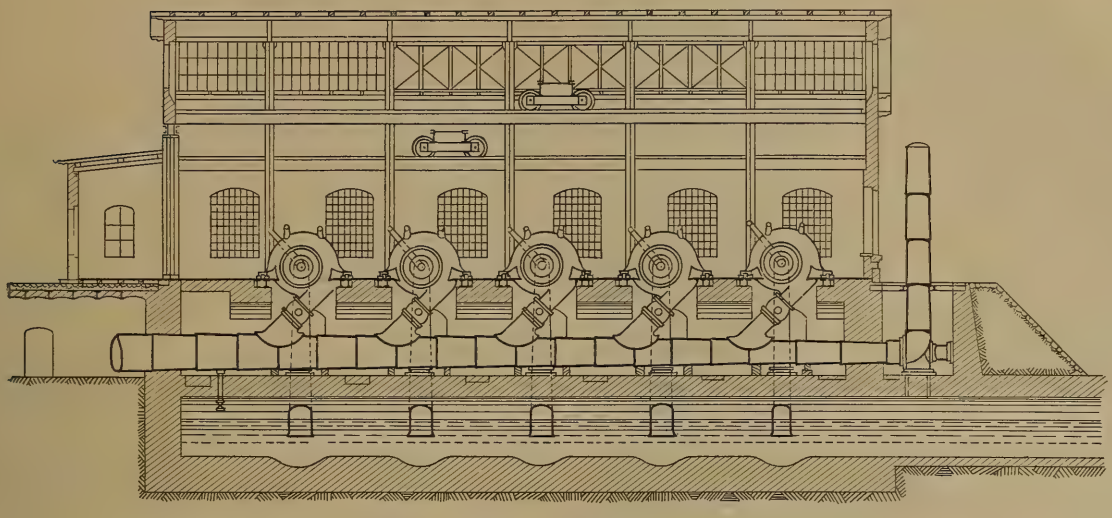
The turbine is a very old device. Hero, of Alexandria, is credited with having first constructed one in the year 130 B. C., while Eytelwein, in 1807, fully worked out the mathematical principles of the water-wheel, and Fourneyron invented the modern type of reaction turbine a quarter of a century later. But although old, the turbine has been a little used invention, and until the closing years of the nineteenth century no such water-wheels of large output had been constructed. The building of 500, 1000, and 5000 H. P. turbines for power installations was, therefore, practically a new industry. The demands made by electrical engineers in this direction have been fully met by turbine builders, and there seems no reason to doubt that the ability to construct and govern these huge water-wheels will keep pace with the progress in the dynamo industry.

The improvement in the efficiency of both dynamos and turbines, and the ability to build units up to 5000 H. P. that will run satisfactorily 300 days in the year, is the second factor which has contributed towards the wonderful advance in recent years. Finally, there is the demand for electric power which has sprung up in connection with the new electro-chemical and electro-metallurgical developments of the last fifteen years. Aluminium, calcium carbide, carborundum, the chlorates of potash and soda, bleaching powder and alkali are now being produced in large and increasing quantities by electricity generated from water power. It is certain

THE TWO PENSTOCKS TO THE POWER HOUSE



ANOTHER VIEW OF THE POWER HOUSE INTERIOR SHOWING THE TWO ROWS OF GENERATORS



A SECTIONAL ELEVATION OF THE POWER HOUSE

that had this outlet for hydraulic power been lacking, the development and growth of hydro-electric installations would have been much slower than has been the case. Though in the future large industrial communities will undoubtedly spring up in the vicinity of large waterfalls, this has not been the case in the past, and the more important hydraulic power stations exist to-day chiefly in districts remote from the manufacturing and industrial centres of the world. Although people talk glibly about the transmission of power, it still costs much to build and maintain a bare overhead network of, say, twenty miles radius, and in some cases the cost and losses due to transmission double the cost of the power to the consumer. With underground cables the expenditure upon distribution is enormously increased.

The possibility of transmitting the power many miles to the distant consumer has not, therefore, been the chief factor in bringing about the developments that are to be seen to-day on every hand. It seems probable that whenever electric power is used on a large scale in the future for manufacturing purposes, the factory or works will be located close to the generating station. The supply of power to small, scattered home industries, as in the St. Etienne silk weaving districts in France, or in the watchmaking industry of Geneva, is exceptional, and the proportion of the power generated at water power stations utilised in this way does not at present equal 5 per cent. of the whole.

In the past manufacturing centres have been formed in or near the great coal mining districts of Europe and America, because it was essential for cheap manufacture to command cheap supplies of coal. This law of proximity to the source of power will still apply in the new era upon which we are now entering. The factories and works at the latter end of the twentieth century will, therefore, most probably be found grouped around the large hydraulic stations, and that at Jajce, here described, is likely to become eventually the centre of a thriving industrial community.

SOME RECENT AMERICAN INDUSTRIAL CONSOLIDATIONS

AND THE MEN WHO ORGANISED THEM

By George Ethelbert Walsh

IN the first six months of the opening year of the twentieth century the consolidation of American industries has been so phenomenal that it marks an entirely new era in methods and aims of industrial and manufacturing life, revolutionising, to a large extent, conditions that heretofore prevailed, and foreshadowing changes in the near future that few can measure to-day. The spirit of consolidation has suddenly broken forth in nearly all lines of work, and the rapidity with which one after another of the manufacturing or producing industries has organised into trusts or combinations has produced a startling effect which has been felt everywhere. Although these consolidations have appeared almost simultaneously, the conditions favouring their growth and development have long been apparent to those familiar with American industrial life. There was, indeed, long preparation for the final events, and the actual consummation of the plans was merely the logical sequence to the events leading up to it.

The organisation of capital for self-protection is one of the prime essentials to success. There is no fight so bitter and disastrous as that of capital against capital. The history of American railway development is full of examples of this. The fierce competition between rival roads, the unnecessary waste of capital in constructing parallel lines, and the battles of the financial managers in the money markets of the country, furnish sufficient data to show that a war waged by capital against capital is fruitful of the greatest national harm. It is possible that the eventful history of American railway development served a useful warning to industrial organisations, and manufacturers and producers thus displayed more shrewdness than the old railroad kings did in the management of their affairs.

The keynote to the recent industrial consolidation movement, from the manufacturers' point of view, is that of

ANDREW CARNEGIE

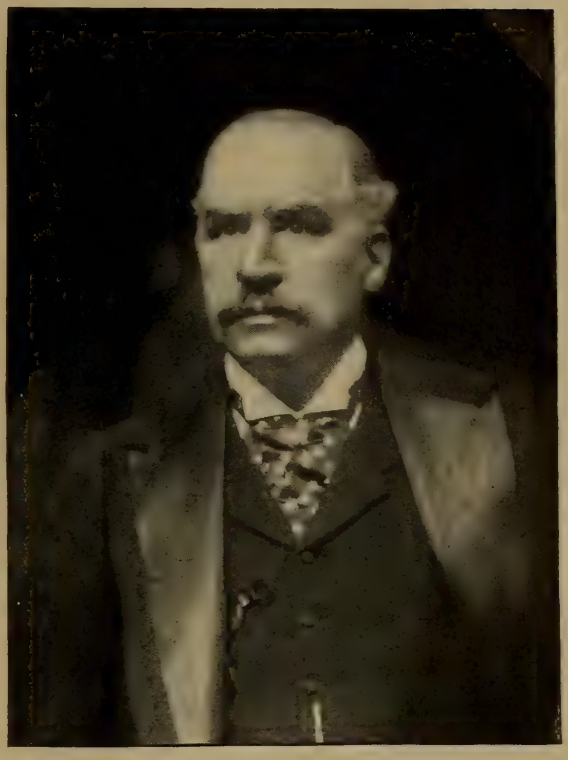
economy of methods. By eliminating the danger of great industrial wars and competitions, the organisers of the large companies succeed in shutting off one

of the most threatening avenues of waste and loss. Industrial strife and warfare were ruinous to methods and capital. Organisation and consolidation were fruitful of the highest commercial and financial results. Economy in shop practice and plant operation has long been one of the mainstays of American manufacturing success, and this could be extended by the consolidation of rival interests so that no two shops would duplicate each other in the production or sale of unnecessary goods. Wasted energy and capital could thus be avoided.

The organisation of the great steel plants proved how important an effect the economy of methods in mining, producing, and handling iron ore and the finished products could be made. Steel and iron were cheapened through this process, and each steel plant sought to make the production less expensive than all other rivals. The manufacture of the products reached a point of perfection where neither more capital nor improved methods could change the cost of manufacturing, and the danger of a fierce, competitive strife between the big concerns brought about the formation of what is now the largest so-called "trust" in the world.

The United States Steel Corporation was originally organised with an authorised capital stock of $850,000,000, with a bonded indebtedness of $304,000,000; but early in April, 1901, the capital stock was increased to $1,100,000,000, equally divided into preferred and common shares, so that, with the $304,000,000 of bonds, the total securities issued by the corporation amounted to $1,404,000,000. The increase in the capital was for the purpose of securing the property of the American Bridge Company, the Lake Superior Consolidated Iron Mines, with railroads and other extensive ore-mining properties in Minnesota.

The organising geniuses of this remarkable company were chiefly J. Pierpont Morgan, Charles M. Schwab, Henry C. Frick, and Andrew Carnegie. The other names on the board of directors are well known in the business world. They include Elbert H. Gary, P. A. B. Widener, E. C. Converse, and many others of prominence. The board of directors included also men of conservative habits and philanthropy, whose works and words have always been directed toward the upbuilding of industries that would have a permanent good effect on the country, and whose patriotism and zeal in the interests of the working classes have never been doubted. The names of such men as Abram S. Hewitt, William E. Dodge, and Clement A. Griscom carried moral weight and conviction that the mere aggregation of capital might fail to do.



J. PIERPONT MORGAN

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The Carnegie steel interests first formed the nucleus of this vast consolidation. Two years ago such an organization of steel interests was proposed by a group of financiers who had secured an option on Carnegie's plants, but the time was not ripe for its consummation. Then came the trouble between Carnegie and Frick, and in the litigation which followed, the astounding revelations of the profits of the group of steel plants operated by these two men produced widespread interest and wonder.

HENRY CLAY FRICK

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Carnegie's estimated share of profits for the year 1900 was placed at $24,867,000. This profit was made on a group of steel plants which Carnegie controlled. The Carnegie Steel Company, Ltd., organised in 1892 with a capital of $25,000,000, grew in value until, in the papers in the Carnegie-Frick suit, it was stated that the entire property was valued at $250,000,000, and that Mr. Carnegie himself had avowed that he could sell it for $500,000,000. This enormous increase in valuation, based on the actual earning powers of the Carnegie steel mills, probably hastened the formation of the steel "trust."

The building up of the Carnegie mills is one of the most interesting chapters in American industrial life, and it is of special importance in view of the fact that many of its leading organisers are prominent in the new steel consolidation. Andrew Carnegie was thirty years of age before he began his career as an iron and steel manufacturer, but his keen insight and masterful spirit enabled him to build up his colossal business within a comparatively short time. He was fortunate in the selection of his partners and assistants, and probably his success is due a good deal to his ability to find the right man for the right position. He discovered the abilities of Henry Clay Frick and went into partnership with him, and because Frick represented an entirely different temperament from Carnegie's, the two made a masterful team. Carnegie was conservative; Frick was daring and progressive, inaugurating changes that the former alone would never have undertaken. The great steel magnate had implicit faith in his partner, and during the latter part of Carnegie's business career Frick was given almost complete control of the vast steel interest. He conducted the memorable Homestead campaign against the strikers and practically won his point, forcing the Carnegie mills away from the control of the labour unions. He was a born fighter and disciplinarian, and won his way in spite of all obstacles, contributing mightily to the upbuilding of the great steel works. His influence in the board of directors of the United States Steel Corporation must be somewhat of the same nature as it was in the old Carnegie Company.

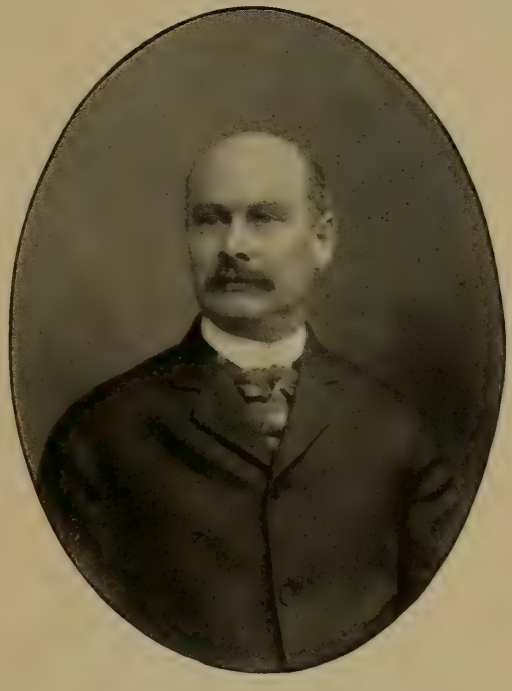
CHARLES M. SCHWAB, PRESIDENT OF THE UNITED STATES STEEL CORPORATION

Charles M. Schwab, the president of the steel "trust," is also a protégé of Carnegie. He began his engineering career as stake driver in the engineering corps of the Edgar Thomson Steel Works, and finally became chief engineer of the Homestead steel plant. Carnegie took kindly to the energetic young fellow, and soon learned to rely upon him with the utmost confidence. From one position to another he was advanced until he became superintendent of the Homestead plant. Having risen from the ranks of the workmen, he knew their methods and aspirations better than most men, and he succeeded in establishing a more cordial relationship between employees and employer than ever before existed. He was careful and exacting in his management of the mills, but he dealt with the men so well that they all liked him. In 1896 he was made president of the Carnegie Steel Company, and was in full charge of it during its most prosperous era.

It was his personal association with the workmen that won for him decisions from the labour unions and disaffected men which could not be obtained by any other plants. He met the men at their own amusements, encouraged them by offering premiums and rewards for faithful work, and won their goodwill and support in numberless similar ways. His rise in the industrial world has been unprecedented, and as president of the United States Steel Corporation he receives the largest salary of any man in the world. Not only this, but he is one of the youngest of presidents of great corporations, having not yet passed his fortieth birthday.

J. Pierpont Morgan, the financial organiser, and practical head of the steel "trust," is one of the most discussed men of the day, and his operations concern more nations than one. His recent purchase of a British steamship line and other franchises has given him an international fame. It was a stupendous undertaking to consolidate such gigantic interests as those represented by the present steel "trust." None but a Titan in finance and organisation could have accomplished it. The vastness of the project almost fails one's imagination when the difficulties of adjusting the shares of the different companies are considered. For weeks and months the resources of ten great trust companies were taxed to their utmost to perform the mere clerical work of receiving the old stock and calculating how many shares of the United States Steel Corporation were to be issued against it.

Mr. Morgan is primarily a financier and railroad organiser. From the days of 1869 when he drove Gould and Fiske



ELBERT H. GARY

from the disabled Albany & Susquehanna Railroad, and made it a paying and self-sustaining property, he has been a prominent figure in railroad reorganisation. He was known by his associates as a reconstructor, rather than a destructor, of property. He succeeded the old railroad kings, whose policy was, first, to ruin a road, and then to secure control of it at a nominal figure. His policy was to take hold of old properties that had been disabled and build them up, and a dozen or more roads owe their present prosperity to his ability in this respect. From railway organising and reconstructing Mr. Morgan has more than once turned

to industrial arbitrations, proving himself as successful a peacemaker as he was a financier. In Great Britain and on the Continent he is better known than any other American capitalists, and he has such extended influence that foreign investors and bankers are willing to loan their money on any securities or stocks with Mr. Morgan back of them. On several occasions he has averted panics on the New York Stock Exchange by announcing that all the ready money needed could be obtained from him at low rates of interest. This was made possible by his enormous borrowing privileges which his influence commanded in Europe.

In the present year Mr. Morgan has completed two of the greatest financial transactions in the history of American affairs. One was the consolidation of

P. A. B. WIDENER

the railroads for trans-Pacific traffic, which gave the so-called "community of interest" control of all the leading systems to groups of capitalists working toward the same end. This movement toward concentration of railroad interests was in harmony with his other gigantic industrial consolidation, which practically combined all the important iron and steel manufacturing plants into the huge corporation above mentioned.

The organisation of the United States Steel Corporation by Mr. Morgan has been called by more than one economic writer the beginning of the world's greatest revolution, with promises the most deeply fraught with results to the human race. The full meaning and extent of this consolidation of steel interests are not appreciated by those outside of the business. President Schwab has outlined some of the advantages and reasons for such consolidation, and the recent payment of a good dividend on the enormous stock shows that the trust officers were not deceived in their estimates.

The great steel organisation contemplates controlling the markets of the world as well as those of the United States, for, in the words of its president, "a concern that produces its own raw materials, and works them up through the various processes until it delivers the manufactured product in the domestic or foreign market, can work on a narrower margin all around, and yet do full justice to its stockholders and employees. Naturally, it can control in the markets and develop its trade where a concern working under less scientific processes would be shut out. The iron business was kept back in the United States for many years because there was no connection between the various industries on which it depended. The ore deposits were owned by one set of men. The coal deposits were owned by another set. The coke was made in a hundred different places, scattered throughout several States, under separate management. The mills and furnaces, in turn, were owned separately; and when these mills and furnaces, having bought their iron here and their coke there, and their other products elsewhere, finally produced their iron and steel. there were still other processes that the product had to go through at other points before it could finally be landed in the market. Everything was disconnected and disjointed. It was not until the whole was welded into a continuous chain under

EDMUND C. CONVERSE

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CLEMENT A. GRISCOM

one management that the American iron industry began to make the giant strides which have carried it now into a position where it dominates the whole world. Now we mine our own iron and our own coal; we make our own coke. We carry these products on our own vessels and on our own railroads to our own furnaces, and then we carry the raw steel and the raw iron to our mills and other plants, to be worked up under our own supervision into final shape for direct use in construction. Nothing is left to chance. Every step of the process is worked out in advance. All waste is cut off. Every hand that is laid on the production pushes it along."

Fully two-thirds of the available iron ore in the United States is owned or controlled by the big steel corporation, and negotiations are being constantly made to secure more. Up in the Great Lake regions it absorbed the Rockefeller interests in mining property, which included the great Mesaba range and the Lake Superior Consolidated Mines. The Mesaba range alone in 1900 produced 1,500,000 tons of ore, and proved up 500,000,000 tons of ore lying on the ground. The total amount of yield of the "trust's" mines in the Lake regions last year was 10,684,934 tons, which is a little more than half the total output of iron ore for the whole United States.

But great and vast as its capital and interests may be, the United States Steel Corporation does not in any sense monopolise the whole business of mining iron ore, or in turning out special steel and iron products in the United States. Its position, however, is so paramount and commanding that it may have the power to fix the prices and conditions in most markets of the world. The corporation and its directors have repeatedly disavowed any intention of aiming to monopolise the business to the disadvantage of the consumer; but while it will strive to make money, it will be in a position to do this by better methods of manufacturing and by the regulation of supply and prices so that violent fluctuations will not cause alternate periods of great depression and unwise expansion. If it can succeed in this, it will prove not the unwise and threatening octopus that many have been induced to anticipate.

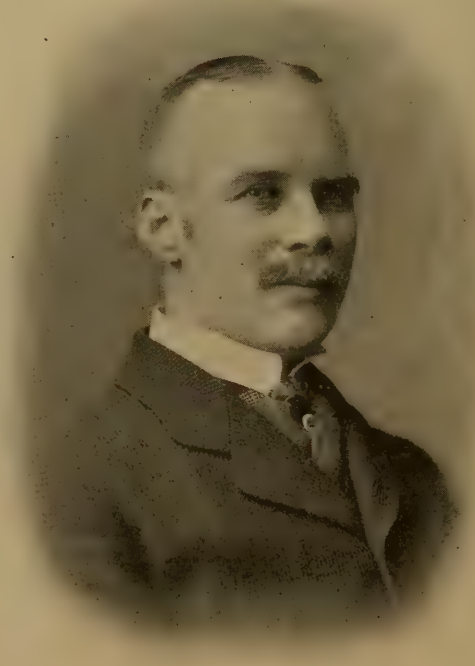
Unintelligent competition has been

CHARLES R. FLINT, THE "FATHER OF TRUSTS"

cited as one of the most striking reasons for the modern consolidation movement of industries. The fear of this has driven the large manufacturers to the necessity of pooling their interests. Unintelligent competition is described as the most ruinous of systems, caused by manufacturers who sought to cut under all rivals without counting the cost. If one manufacturer could produce an article for, say, a dollar, a rival might reason that he could do it for ninety-nine cents, while a third might attempt to do the same work and sell the product for ninety-eight cents. In the rate-cutting competition there would be little time to make thorough investigations as to the actual cost of the articles, and in time failures would follow. The consumer, it might be, would find some temporary benefit from this system; but the manufacturers would lose, business would be demoralised, and eventually the consumer would have to pay higher prices for the articles until the machinery of manufacture was once more reorganised and running smoothly.

It has been this view of business that has influenced the consolidation of industrial interests which began in 1889, when the movement was considered phenomenal. In 1900 the high-water mark was supposed to have been reached; but with the example set by the great steel corporation, the first six months of the present year have dwarfed all other records. There have been grouping of railroad combinations by the score, and reorganisations and consolidations of street railways innumerable. Other great combinations, which furnish only a part of the consolidations so far reported, include the shipbuilding combination, with a capital of $65,000,000; the tin can trust, with a capital of $88,000,000; the locomotive combination, with a capital of $50,000,000; the stationary engine and machinery manufacturers, with a capital of $50,000,000; the glassware factory "trust," with $20,000,000; the watch manufacturers "trust," with $75,000,000; the agricultural implement combination, with $50,000,000, and many others of lesser note.

One of the most important of these consolidations is the Allis-Chalmers Company, formed about the beginning of May of this year with a capital stock of $50,000,000. The firms that have entered into this combination are among the leading manufacturers of steam-engines and mining machinery in the United States. The object of the consolidation



W J. CHALMERS, OF THE ALLIS-CHALMERS CO.

was twofold. One was to obtain better and surer methods in manufacturing, similar to those of the steel company; and the other was to co-operate in extending the foreign market demand for American machinery. In recent years American machinery has found its way all over the world, and the new markets have proved profitable and lucrative. But there has always been a good deal of uncertainty about the demand. Without adequate information concerning the needs of foreign buyers, a good deal of loss was experienced in attempting to cater to them, and it was concluded that a single combination of manufacturers could work out a solution better than a score or more of separate concerns. The demand for American mining machinery in particular was rapidly growing in South America, South Africa, and Australia, while Great Britain, too, was beginning to use a good deal of it. To encourage and systematise this demand the consolidated machinery organisation of manufacturers was formed. Since it has been in operation the exports of American machinery have notably increased, showing for the six months of the new year the largest total ever before recorded.

The locomotive consolidation, which followed the Allis-Chalmers Company, was likewise capitalised at $50,000,000. This consolidation is known as the American Locomotive Company, and includes most of the locomotive works of the United States, excepting the Baldwin Works at Philadelphia and one or two smaller concerns near Pittsburgh. Mr. Samuel R. Callaway resigned from the presidency of the New York Central Railroad to accept the leadership of the locomotive "trust," and, as president of it, his influence will be far more extended and powerfully felt in the industrial world than it was during his railway presidency. The future of American machinery exports must be largely determined by the plans and success of the new locomotive combination. American locomotives have already entered into competition with those manufactured in other countries, and the consolidation of the American companies into one company is for the purpose of stimulating this demand.

Impressed by the fact that there was a steadily increasing demand from other countries for American locomotives, while no general effort had been made to secure foreign orders, President Callaway conceived the idea of uniting the different plants into one huge consolidation, which would not only simplify the construction, but unify the efforts to find markets for what surplus there might be. But, indeed, there has never been a time when there was a surplus of American locomotives. American manufacturers in the past have been hard pressed to keep up with the home demand, and orders for more than a year in advance have already been placed with the new organisation.

C. B. ORCUTT, PRESIDENT OF THE NEWPORT NEWS SHIPBUILDING & DRY DOCK CO.

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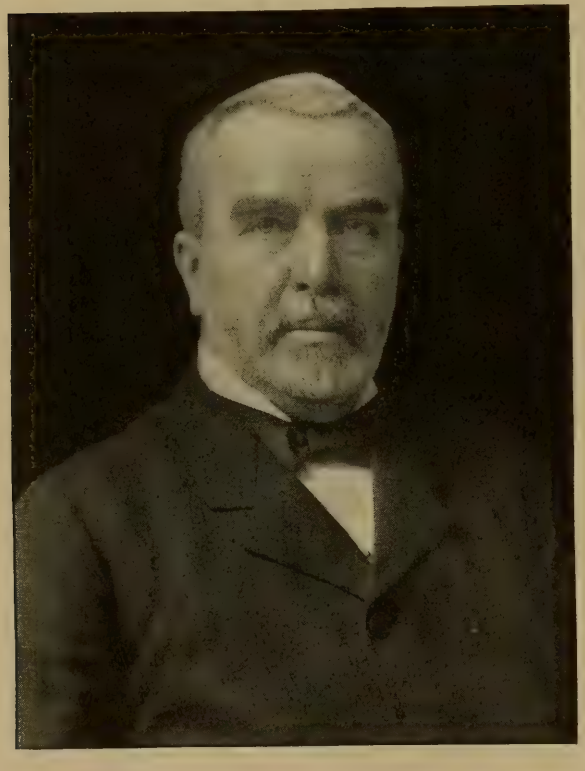
With the methods of the consolidated companies the output will rapidly increase. Last year the total output of American locomotives amounted to 3153,—the largest number ever built in the United States in a single year. This showed an increase of more than

27 per cent. over the output of 1899, when 2473 locomotives were built in American shops, which number was considered a record-breaker at the time. The gradual increase in the output is best shown by the figures, which place the total manufactured product for 1896 at 1175; in 1897 at 1251; and in 1898 at 1875 locomotives. The output of the present year will eclipse anything heretofore recorded.

But in exports the consolidated locomotive company does not anticipate much increase over those of 1900, for the simple reason that it is impossible



S. R. CALLAWAY, PRESIDENT OF THE AMERICAN LOCOMOTIVE COMPANY

to do more than supply duplicates abroad and hold old customers. It will be a year or two before the company will be in a position to push with energy new foreign orders. The exports of American locomotives last year were 505, while 514 were sent abroad in 1899, and 554 in 1898. This decline in the exports has been ascribed to the more prosperous conditions in the United States, and the placing of domestic orders which absorbed nearly all the output of the American shops.

The consolidation of the different agricultural implement companies into one organisation with a capitalisation of $50,000,000 is another industrial change of momentous importance. The United States have naturally become the greatest manufacturers in the world of agricultural machinery and implements. The great farms of the American West are insatiate absorbers of agricultural implements, and the manufacturers further have developed an export trade in their products that is rapidly increasing. The industrial evolution of this trade has been remarkable. Beginning in 1840 with the manufacture of the Hussey and McCormick reaping machines, the industry has rapidly advanced to its present commanding position. To-day the estimated annual production of reapers in the United States amounts to 180,000 self binding harvesters, 250,000 mowing machines, 18,000 corn harvesters, and 25,000 reapers. One large factory alone in 1898 produced 74,000 self-binding harvesters, 107,000 mowers, 9000 corn harvesters, 10,000 reapers, and 75,000 horse-rakes. But these implements represent only a fraction of the output of the agricultural implement industry. There are hundreds of thousands of threshers, seeders, ploughs, harrows, and hand implements manufactured every year.

The capitalisation of the American Agricultural Implement Society will be increased from $50,000,000 to $75,000,000 within the year, and great as this sum is, it no more than represents the full value of the immense industries combined in the "trust." There is no over-valuation in the stock, for the output of the combined factories is so enormous that dividends are assured from the outset. In the exports of American agricultural machinery, the figures of last year were the largest on record; but for the first six months of the new century the exports almost equalled those of 1900. South America, South Africa, and Australia are large buyers of the American machinery. Many of the American inventions for farm labour-saving are manufactured

in no other country in the world. With the addition to American territory of Porto Rico, the Hawaiian Islands, and the Philippines, there has grown up suddenly an imperative need for better machines for harvesting and utilising sugar cane. Within the current year large inducements have been offered to inventors for machines that will simplify the work in the cane fields. An important branch of the machinery "trust" will be the manufacture of implements for tropical agriculture, which, according to the nature of the crops, must differ essentially from those in use in the temperate zone.

The shipbuilding combination, with a capitalisation of $75,000,000, was slow in organisation, and many obstacles repeatedly delayed final consolidation. But recently the organisation was perfected under the name of the United States Shipbuilding Company, and included some of the largest shipbuilding concerns in the country. The American Tin Can Company, with a capitalisation of $88,000,000, was organised for the purpose of unifying the interests of a number of large factories which had sprung up in all parts of the country, and to open up and retain markets at home and abroad. The consolidation has yielded results that have apparently justified the expectations of the organisers.

All trades and industries show the irresistible tendency of the day toward consolidation of interests and the centralisation of power. The ambition of the "trusts" is to cheapen production and control the markets. Besides those mentioned above, there is the consolidation of the watch manufacturers in an organisation with a capitalisation of $75,000,000; a combination of cotton duck manufacturers, with a capital of $50,000,000; and carpet, packing, egg, and cereal consolidations representing various capitalisations of from five to twenty-five millions. The lighting and street railroad companies all over the country are forming into industrial combinations for promoting their interests and to eliminate rate-cutting and unintelligent competition. The great companies which control the sources of natural power and fuel, such as the oil-field companies, coal companies, and electric power organisations, are being amalgamated from the Atlantic to the Pacific. Indeed, there is hardly an industry of any importance that is not represented by one or more consolidated corporations seeking to lessen the cost of production and control the markets.

This new principle in American industrial life has completely revolutionised past conditions. Each week and month add a chapter to the remarkable industrial evolution. Combinations succeed combinations, and enormous capitalisations appear to be obtained with comparative ease. Small and unprofitable shops, factories, and mills are being abandoned, and the new, modern, and profitable ones are being enlarged and perfected. Centralisation of energy and talent, as well as of capital, is thus increasing the quality and quantity of the output. All this great change is being effected without great revolutions in public opinion or change in the smooth course of business. The movement is the natural outcome of the conditions of the time, and, so far, it has created little actual injury to any; but what the future may reveal is something that is beyond prediction to-day.

SOME ELECTRIC RAILWAY FEATURES IN SICILY

ON THE PALERMO–ROCCA–MONREALE TRAMWAY

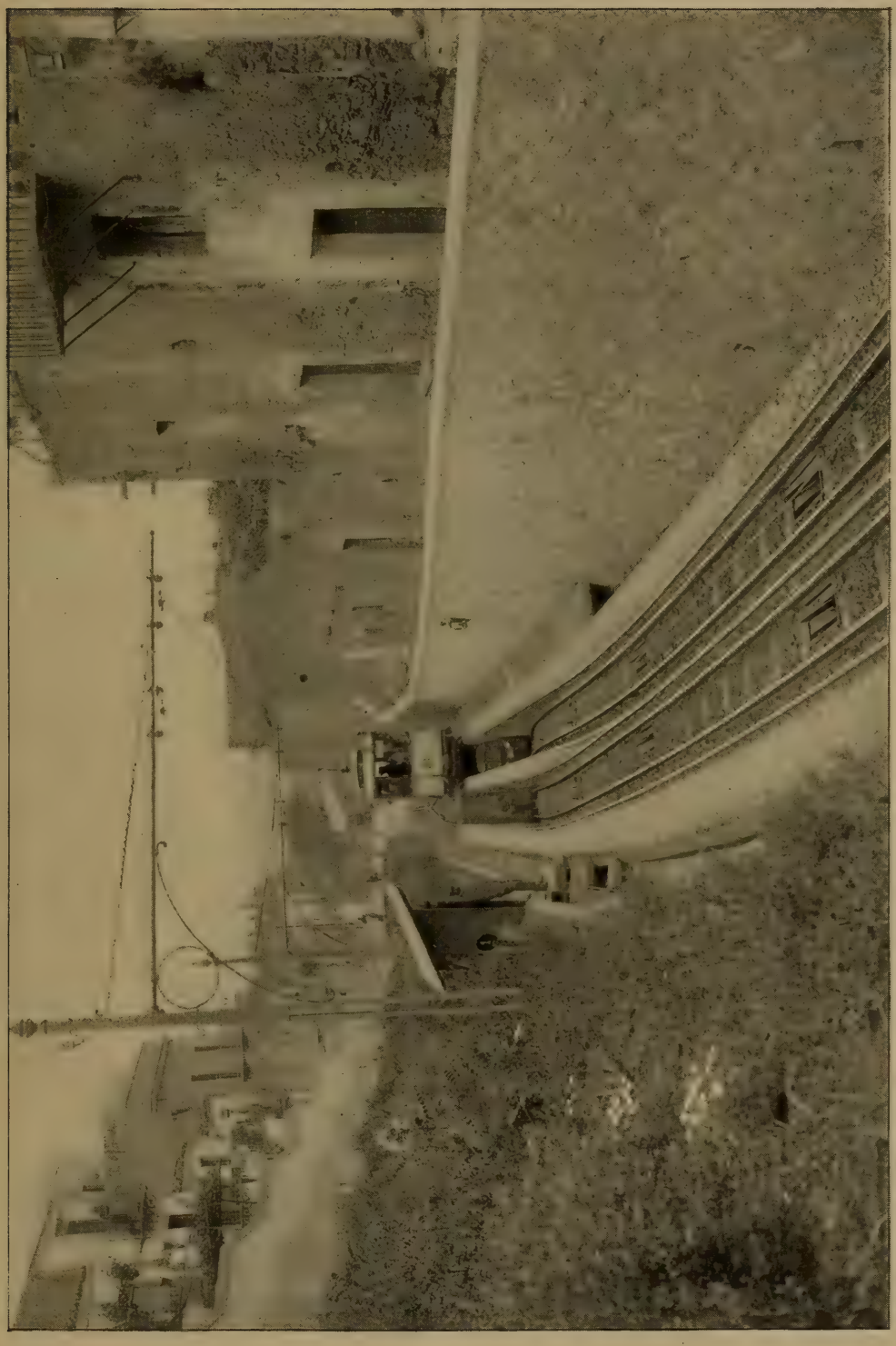
By Enrico Bignami

THE TURN-OUT ON THE CABLE SECTION ON THE MONREALE LINE

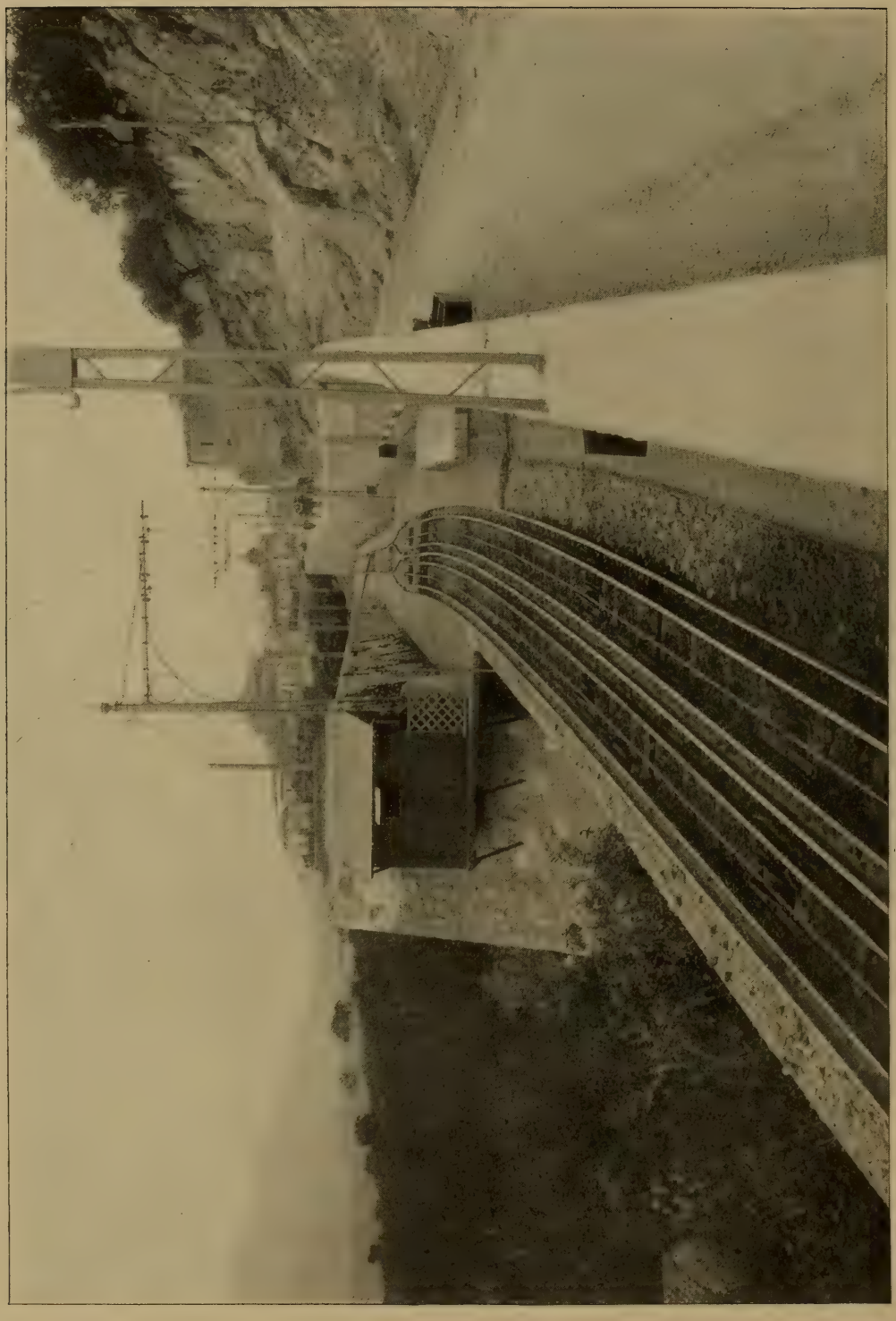
IT is unusual to find on one short line of tramway a combination of electric and cable systems, so that it is all the more interesting to note that these two have been brought together on one of the branches of the Palermo line, operated by the "Societè Sicula Trawmays Omnibus."

The Palermo electric tramway proper is a belt line encircling the town, and up to somewhat less than two years ago had been operated by horses. The belt line scheme had been prompted, or, rather, had been made compulsory, by the narrowness of the streets, which presented discouraging difficulties to the construction and working of any kind of crosstown system. From the belt line several branches reach out to some of the surrounding localities, one of them running to Rocca, and from that point a further extension to the little town of Monreale was completed early last year. It is on this short section that the combination system above mentioned is in operation. The whole length of line is less than two miles, but in that distance a remarkable grade has to be overcome, quite too steep for ordinary railway operation; hence, the cable adjunct.

In equipping the line, however, provision had to be made for the fact that only one standard type of car could be



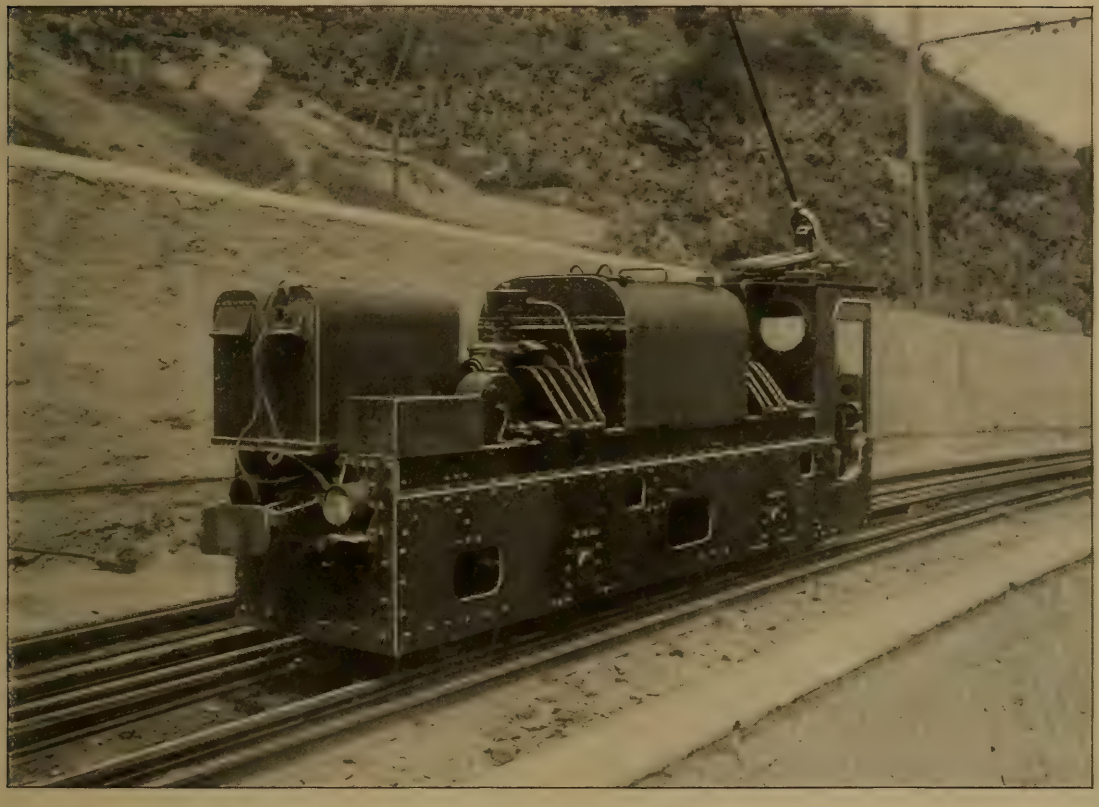
THE LOWER TERMINAL OF THE CABLE INCLINE, SHOWING THE MOTOR OR BRAKE CAR IN THE POCKET ARRANGED BENEATH THE REGULAR TRAM WAY



THE UPPER TERMINAL OF THE CABLE SECTION

used on the whole system,—in other words, the cars on the Monreale mountain branch, as it might be termed, had to be serviceable on the other sections of road as well, and the only way, therefore, in which the steep climb could be accomplished was by having special auxiliary motor cars to help the others along. A pretty clear idea of how the installation is arranged can be obtained from the illustration on page 465.

From Rocca to Monreale the line is made up virtually of three sections,—



THE MOTOR CAR USED ON THE CABLE SECTION

the first a single-track length of about 700 feet; the second, a three-rail double-track portion about 1200 yards long, with one rail common to both tracks, and with a turnout half way; and the third, again a single-track section, about 800 yards long. The double-track part is the interesting one, for it is there that the cable and the auxiliary motor cars are employed. The electric current is supplied from an overhead conductor,—the conventional overhead trolley system. The auxiliary motor cars, two in number, run on a special narrow gauge track, laid between the regular track, and are connected by a cable, so that when one is at the lower end of the double track section, the other is at the upper end. But aside from its extra motor equipment, each of these cars serves further as a safeguard to operation by being fitted up with powerful track brakes, which, to a large extent, eliminate the chances of the passenger cars getting beyond control and running away. With the cable disposition as noted, the descending auxiliary car, or brake car, as it has also been termed, together with the weight of the passenger car behind it, helps to haul up the ascending cars on the other track, gravity thus playing some part in the traction problem.

The brake cars, it is to be noted, are placed at the rear of the passenger cars, and the way in which this is accomplished makes one other noteworthy feature of the line. Here, again, reference to the illustration on page 465 will be found helpful. At the lower

terminal of the double-track section there are arranged between the tracks, in the manner shown, properly graded pockets, each large enough to easily accommodate one of the brake cars, so that the regular passenger car coming from Palermo can pass over it. At the same time, the other car, coming from Monreale at the head of the grade, runs up behind the upper brake car there and is coupled to it. The two cars,—brake car and passenger car,—from the upper station descend several yards until the brake car at the foot of the grade, which thus is drawn from its pocket, reaches the car at that end and with which it has to climb. After reaching the head of the incline the passenger car continues on its way alone, while the brake car is ready to return with another car which may have arrived by that time. The down-train of brake and passenger cars has in the meantime reached the lower station where the regular car stops for a few seconds to give the brake car time to enter its pocket, after which it continues its trip on to Palermo.

The whole system was planned and installed by the "Continentale Aktiengesellschaft für Elektrotechnische Unternehmungen," of Nürnberg, Germany, in conjunction with the "Elektricitäts Aktiengesellschaft," formerly Messrs. Schuckert & Co., also of Nürnberg.

PARALLEL OPERATION OF ALTERNATORS

By Charles F. Scott, Chief Electrician of the Westinghouse Electric & Manufacturing Company

THE problem of parallel running of alternators which has recently come into prominence because it has become a necessity in the operation of large power stations, has been considered from a number of standpoints The electrical conditions, including the various proportions of the alternators, their self-induction and their field reaction, the flow of idle or wattless current between the armatures, the relative field strengths, are all elements which have received more or less consideration, and sometimes prolonged discussion. The speed of the engines, not only the mean or average speed, but the variation in speed during a revolution, also the weight of fly-wheel, are further elements to which attention has been properly directed.

In a lecture delivered recently before the Franklin Institute, the writer, however, considered the problem from a standpoint somewhat different from those mentioned, not taking up alone the voltage or current or speed, but going at once to that fundamental element for which everything else exists, namely, the power, and to this it may be of interest to make further reference here. We will for the present omit the functions of the system other than its function of receiving power from two or more prime movers and delivering it to a common circuit. We will assume two similar engines carrying similar alternators upon their extended shafts which are connected to common bus-bars and supply an outgoing circuit. We will also assume two similar engines carrying similar gear-wheels upon their extended shafts driving pinions upon a common shaft which supplies power to an outgoing belt. The number of teeth in the gear-wheels may be taken as equal to the number of poles on the alternator.

There is a certain elasticity in the

electrical connection between two alternators which allows a relative displacement between the angular position of the two armature windings with respect to the field poles without injury, provided the displacement does not become too great. When there is a displacement there is a flow of current between the two armatures tending to pull them to a common position, and this force is proportional to the angular displacement. In the same way we may imagine the spokes of the gear wheels to be slightly elastic, thereby permitting a deflection amounting to a fraction of the pitch between two teeth. It is not necessary, therefore, that the two engine shafts occupy exactly the same angular position, but one may be slightly in advance or behind the other. The forces exerted by the two engines upon the countershaft will be different, and there will be a force tending to a common position of the two quite similar to that in the electrical system.

The proper condition for connecting the second engine to the common shaft by means of the gear-wheel when the first is running is obvious. The pinion should not be thrown into the gear-wheel unless the engine has the proper speed and the proper angular position. If the speed of the two engines is not the same just before they are connected together, there will evidently be a severe stress exerted during the extremely short time in which it is necessary to impart the necessary energy to the fly-wheel and other moving parts of the slower engine in order to bring it to the proper speed. A difference in speed of 1 per cent. may involve very great stresses, as the speed must be equalised almost instantly. It is also evident that if the arrangement is such that the pinion and gear-wheel can be instantly forced together when the teeth have not the proper angular position, the result will be in the nature of a blow in order to secure the proper angular position.

The corresponding conditions in the electrical system are also quite evident. If engines and generators are not running at the proper speeds or have not the proper angular positions at the time that they are thrown together, very great stresses will be brought upon the electrical system in order to produce the proper speeds and positions almost instantly.

When the two engines are connected by gearing they must, of course, run at identical speeds. This is true not only in respect to the total number of revolutions per minute and to the time of a complete revolution, but the angular speeds during each revolution must be identical, except in so far as the angular positions may change on account of the flexible spokes with which the gear-wheels are supposed to be provided. If an engine running alone were to vary in angular velocity during a revolution, then there would be no marked effect unless the variation were quite considerable.

For example, if the engine drives the shafting of a mill, the speed would fluctuate slightly; if it drives a dynamo, the voltage delivered would vary with each revolution, but would hardly be noticeable unless the variation were sufficient to produce a fluctuation in the lights which may be supplied. In each case the engine would deliver power at a very nearly uniform rate throughout the revolution. But when two such engines are connected by gearing and one tends to be in advance of the mean position when the other is lagging behind, then they cannot deliver practically constant power throughout the revolution, for the leading machine will tend to carry the greater part of the load, and if the natural fluctuation in speed is sufficient it may even take the whole load. When a part of a revolution is passed the conditions have changed, and the second engine takes the undue proportion of the load. If the two engines were belted to a common shaft, the stretching and slipping of the belt would aid the equalisation of the load so that each engine might be carrying a very nearly constant load.

In the electrical system the analogy is obvious. There will be a corresponding shifting of load from one outfit to the other, similar to that which occurred when the engines were connected by

gearing instead of by alternators. If the electrical connection were made not by alternators, but by direct-current machines, in which there is no requirement as to relative angular position, then each engine and generator would carry very nearly constant load throughout the revolution.

The above considerations indicate that engines for parallel running must be such that when running alone the angular displacement from perfectly uniform rotation must not exceed certain reasonable limits. These limits are determined by the number of poles in the alternator or the number of teeth in the gear and also the angular displacement which may occur without introducing undue stresses in the connecting system, *i. e.*, the current between the alternators in one case and deflection of the steel spokes of the gear-wheels in the other case must not be excessive.

The gear-wheel in one arrangement and the alternator in the other are simply means for transmitting the power developed by the engine. It is essential to keep this simple proposition clearly in mind, as it is sometimes imagined that the power in the electrical system can be regulated or controlled by means of the electrical adjustments of the alternators. In cases where this may be effected, it is because some new adjustment of the engine-governing apparatus has been caused thereby, which, in turn, results in a change of the power developed by the engine. The alternator, like the gear-wheel, simply transmits the power received from the engine. The power developed by an engine is primarily due to the adjustment of its valves. The valves, valve gearing, and the governor must necessarily be looked to as quite important in parallel operation. The requirements upon these elements for parallel running are considerably different from those in other service.

Proper division of load between engines operating in multiple must, therefore, be effected by the governing mechanism. It is sometimes supposed that engines will be well adapted for parallel operation if they do not vary in speed between no load and full load more than, say, 1 per cent. Close speed regulation may be quite unsuited for parallel running. Thus, if one engine falls from 100 revolutions to 99 revolutions per minute when loaded, and a second engine has the same excellence of regulation, but happens to have a speed falling from 100.5 to 99.5 revolutions, then it is obvious that when running at 99.5 revolutions one engine would be adapted for carrying half load and the other for carrying full load. A difference of only ½ per cent. in the natural speed of such engines may tend to a very unequal distribution of load. On the other hand, if each engine falls off 4 or 5 per cent. between no load and full load, a difference of ½ per cent. or 1 per cent. in their absolute speeds for a given load would cause only a trifling difference in the loads which they would carry when operating at equal speeds. It has been found in practice that usually much more satisfactory results are obtained when the speed falls off considerably, and that from 3 or 4 to 5 or 6 per cent. is desirable for good operation.

In considering the effect of fluctuation of angular velocity it was found that the load may rapidly shift from one engine to the other, due to the fact that the speeds must be maintained practically identical, although the natural tendency of the engines may be to produce fluctuating speeds. One engine is momentarily relieved of a part of its load; the ordinary requirement is a readjustment of the governor. The governor mechanism may, therefore, change its position to give a decreased admission of steam. A moment later the conditions are reversed and the engine takes more than its share of the load, thereby tending to give a different adjustment to the governor. The effects of angular fluctuation, however, are necessarily small and rapid, and are not so apt to produce instability in the governing mechanism as certain other causes which may exist, even though the engines have so uniform a turning effort and fly-wheels of so great weight that the fluctuation in angular velocity is inappreciable.

Two engines may be delivering equal

power to a constant load either through gear-wheels or alternators. The load may be suddenly changed. The change in load, either through a momentary increase of speed or other action upon the governors, causes them to act and readjust the valves. When an engine running singly has a change in its load, the governor changes, often going beyond the required position, then returning a little too far, and after several oscillations settling to the proper position. The engine during this time is carrying its new load constantly and is seeking to adjust itself to this new load. When two outfits are running in parallel and two governors are simultaneously seeking the new position required by change in load, it is easy to see how neither governor is left free to find its new position (as it would be if the engine were running singly), because the load may be continuously shifting from one engine to the other. The two governors will have a mutual effect upon each other, as the load on each engine is not constant, but is partly dependent upon the governor of the other engine. If, therefore, the governors are oscillating back and forth about a mean position, it is easy to see how this oscillation may increase in amount. If one governor has moved beyond the proper position and is admitting too little steam, it should then readjust itself for the proper load. But at the same moment the other governor may be in a position which admits too much steam, thereby causing its engine to deliver too much power and thus carry load which should be carried by the first engine. The governor of the first engine, which is already carrying less than the proper amount, may, on account of the decreased load, seek to adjust itself for still less load. This causes a still wider divergence between the two governors, and presently they may both tend to swing back and pass the mean position. The interaction of the governors may thus continue and increase in amplitude until the shifting load from one engine to the other, caused by oscillation in the governor mechanism, may be far beyond permissible limits.

It will be well to consider the conditions which prevail when alternators are driven by water-wheels, where, as is well known, parallel running is comparatively easy. Water-wheels in general give uniform rotation without the angular fluctuations which occur in steam-engines having reciprocating parts and an intermittent admission of steam. The speed regulation of water-wheels is comparatively poor, and the governors are comparatively slow in action. A load gradually applied may make little change in speed, whereas, a suddenly applied load may cause a momentary decrease in speed which will be quickly recovered.

The governor of the steam-engine is often prevented from oscillating by making it sluggish in action by the use of a dash-pot. The dash-pot must allow the freedom of motion essential for regulation under changing load, and yet destroy the delicacy and sensitiveness which produce oscillation and hunting.

Several points in parallel running which are common both to alternators and to gear-wheels have been considered. But there are some elements in alternators which are not common to gear-wheels. These have to do with the E.M.F.'s and the currents rather than with the power. If the wave forms of the two alternators are not similar, but sometimes one and sometimes the other E.M.F. during each cycle is higher, there will be a local flow of current between the two armatures. Again, if the field currents are not equal, the E.M.F.'s would also be unequal if the generators were running separately; but if the armatures are connected with a common bus-bar, the E.M.F.'s are necessarily equal, and an armature current circulates between the two machines which equalises the induction in the two machines. This is a so-called "wattless" current; its function, like that of the field current, is for magnetising, and it does not transfer power. It, therefore, has no mechanical analogue in the gear-wheels, and is not an element with which the engine need concern itself.

THE NEWER NEW YORK

SOME OF ITS NOTEWORTHY ENGINEERING PROBLEMS

By George B. Clark

The bird's-eye view of the city of New York given on page 476, in the following article, explains at a glance, and perhaps more intelligently than any words could do it, why the transportation problem is of such commanding importance in the city proper, or what now, after the chartering of Greater New York, is known as Manhattan Borough. Long drawn-out and narrow as the island of Manhattan is, the immediate development of the city naturally could extend in two directions only,—northward and skyward,—and in both of these it has gone on apace, the now almost traditional New York "sky-scraper" having become the wonder of the world. But with the tall office buildings and the gigantic apartment houses and hotels, each almost a city in itself, traffic congestion has become infinitely worse than it would have been under the more nearly normal conditions of simple northward extension of the town, and each succeeding year the difficulties in connection with it have grown more serious.

Four lines of elevated steam railway, and electric and horse tramways on every thoroughfare running lengthwise of the city, except one, Fifth avenue, on which an omnibus service is maintained, have been unequal to the task of carrying the daily stream of people in comfort and safety. Hence, the need of the underground railway now in course of construction, and of ready means of lateral expansion, across the rivers, by bridges and tunnels, all of which are to be accomplishments of the near future. Mr. Clark in his article tells of some of these and of much else besides that will be interesting to the general reader and to municipal authorities.—THE EDITOR.

THE peculiar geographical and topographical situation of the city of New York has made it the centre of the greatest engineering and constructive enterprises of the world. In order to develop to the proportions destined by the march of civilisation it has been forced to adopt schemes of self-improvement scarcely possible in any other city. Because of its commanding position near the sea, with broad, deep rivers washing either shore, and a safe harbour for the largest steamers afloat, New York possesses remarkable facilities for commercial development; but in spite of these favourable conditions, it would have been difficult for the early settlers to locate a spot anywhere along the coast which would have offered greater obstacles for the spread and growth of a great metropolis than this same Manhattan Island. It has been the glory of New York that it has burst the natural bonds which held it, and swept irresistibly across rivers, flats, and marshes, moving northward, eastward, and westward. But in overcoming these natural impediments to its growth, the city has undertaken gigantic enterprises, the cost of which might easily have financially swamped many small nations, and which, in the aggregate, represents an invested capital greater than the annual expenditures of half a dozen of Europe's small monarchies and principalities.

The newer New York succeeds the chartering of the Greater New York so rapidly that those who witnessed the consolidation a few years ago will scarcely recognise the conglomerate boroughs of the past few years in the perfected city of the near future. The engineering feats which are now in progress will bring to the new city a more unified, central life than ever before existed. Slowly but surely the city is passing through a physical evolution that must completely transform its topography and geography. In the aggregate these improvements represent an expenditure of something like $100,000,000. Nothing but the colossal wealth of a great metropolis could furnish the funds for such improvements without seriously detracting from the regular administration of municipal affairs. Yet in an ordinary sense the expenditure of this sum for self-improvement is scarcely felt by its citizens, and few indeed are more than cursorily aware of the building of the magnificent monuments to New York's future greatness now in progress.

The rapid transit subway, which has been under way for a year or more, naturally attracts most attention because the work extends through the very heart of the city, and its ultimate completion means rapid transit facilities which will benefit thousands. It will be one of the greatest engineering feats of the age. It is expected that within two years trains will be running through the very bowels of the city, giving perfect rapid transit to an island which, by its general conformation, seemed to present an almost hopeless problem. In the years of despair and "hope long deferred" skeptics repeatedly proclaimed that rapid transit for New York was an impossibility. Engineers had promised to burrow under the rivers and carry the population out to the districts beyond; others would swing innumerable bridges across the swift-flowing streams, and showed on paper how the congested city could eventually be relieved of its surplus population. But at the beginning of the present century it was evident that the city would need all these, —tunnels under the rivers, and bridges across them,—and the subway rapid transit as well

So it is that New York is building the greatest subway system of the world, putting millions into it, with fine disregard of cost or expense, but with very careful consideration of its ultimate effectiveness. No engineering piece of work was ever more seriously and carefully studied and scrutinised from every point of view before the contract for its performance was signed. Consequently the public professes the utmost confidence in the new scheme, believing that what expert and practical opinion has decided as the best will satisfactorily solve the problem of rapid transit.

A total expenditure of about $40,000,000, including the cost of terminals and changes not in the original contract, will be required for the completion of the gigantic undertaking. Few modern undertakings of an engineering character have cost half as much as this, and

FAC-SIMILE OF AN ORIGINAL MAP OF THE CITY OF NEW YORK MADE IN 1728.

LOOKING UP BROADWAY, THE CITY'S MAIN ARTERY OF TRAFFIC

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when completed the new subway tunnel will represent one of the wonders of modern municipal development. Not Babylon with its wonderful hanging gardens, nor Rhodes with its gigantic Colossus spanning its harbour, nor Rome with all its splendid viaducts, military roads, or mammoth triumphal arches, ever spent this amount of money for a single improvement. But great as the new subway rapid transit tunnel may prove, it may be eclipsed before long by another under the Hudson river. In her growth New York has only two methods of crossing the rivers that bound her on either side. She must span the streams with suspension bridges, or burrow deep under the bed of the rivers in the shape of tunnels. While the bridges are costly luxuries, they are comparatively cheap when compared with tunnels. The first real tunnel under the water that is likely to connect Manhattan with the rest of the

world will be built in connection with the present rapid transit subway to extend its usefulness to the borough of Brooklyn. The subway extension will run from the New York City Hall to the lower end of the town, known as the Battery, under ground, and then cross under the East River to Brooklyn. According to the plans drawn up, it will cost about $8,000,000 to build this extension, but it will inaugurate the era of tunnels for New York which is bound to follow that of bridges.

The project of tunneling the Hudson River to connect New York with the mainland may soon be revived and carried to completion. The old tunnel which was commenced many years ago has long been abandoned. Millions of dollars were invested and wasted in this enterprise. It is estimated by some engineers that $100,000,000 will be required to tunnel the Hudson effectively. Yet even this amount will not prevent the revival of the undertaking unless bridging the river should be considered more serviceable and satisfactory. The powerful railroad corporations that have their terminals at Jersey City, directly across the river, must eventually push their lines into the centre of Manhattan. At the present time the Long Island Railroad Company is preparing to build a tunnel under the East River to connect its Long Island City terminal with some point on Manhattan. The Pennsylvania Railroad Company, which controls the Long Island Railroad, is at present figuring on the scheme of building a 3000-foot span, eight-track railroad bridge across the Hudson River to connect with the Long Island Railroad tunnel, and thus not only secure entrance into New York, but make good connections with Boston and all Eastern points. The

THE CITY OF NEW YORK IN 1665, THEN KNOWN AS THE TOWNE OF MANNADOS, OR NEW AMSTERDAM

THE ABOVE REPRESENTS A COPY OF A MAP IN THE LIBRARY OF THE BRITISH MUSEUM AND AGREES IN EVERY PARTICULAR WITH THE ORIGINAL

A BIRD'S EYE VIEW OF THE CITY OF NEW YORK
BY KIND PERMISSION OF MESSRS. COLTON, OHMAN & CO., NEW YORK

construction of such a bridge has been estimated to cost upward of $60,000,000.

The Hudson River bridge or tunnel will not be constructed until the relative effectiveness of bridges and tunnels across the East River has been definitely decided. The present activity in building tunnels and bridges will soon determine finally whether the city's traffic shall be carried above or under the water. The bridges now in course of construction, or with plans drawn and almost ready for work to begin, indicate, to a certain extent, the wonderful activity in self-improvement now ruling in New York. The city has waited patiently for decades before deciding what course to pursue, but now the growth has exceeded all further resistance, and the various new avenues of overflow are being rapidly spread out. There is first the new East River bridge, with its spans of steel already dangling across the river, which, when fully completed, is to cost about $15,000,000. This magnificent suspension bridge will serve, with its older sister bridge, to relieve the congested traffic which forever flows between Brooklyn and Manhattan. Built of steel instead of stone and masonry work, the huge towers of the new bridge represent the advances made in the last few years in adapting iron and steel to wider uses. The bridge will be far more enduring and stronger than the original Brooklyn bridge, and with proper care it will serve unnumbered generations yet to come.

BOWLING GREEN, THE BEGINNING OF BROADWAY

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This new bridge crosses the swiftly flowing stream within plain sight of the old bridge, and its towers and network of cables can be seen far down the bay from the decks of incoming steamers. But not two miles further upstream there will soon be under way still another bridge, which will be one of the

ST. PAUL'S CHURCH, SHOWING THE ST. PAUL OFFICE BUILDING DIRECTLY BEHIND AND THE PARK ROW BUILDING AT THE LEFT. HEIGHT OF LATTER TO TOP OF TOWERS, 382 FEET; TWENTY-NINE STORIES. HEIGHT OF CHURCH STEEPLE, 222 FEET

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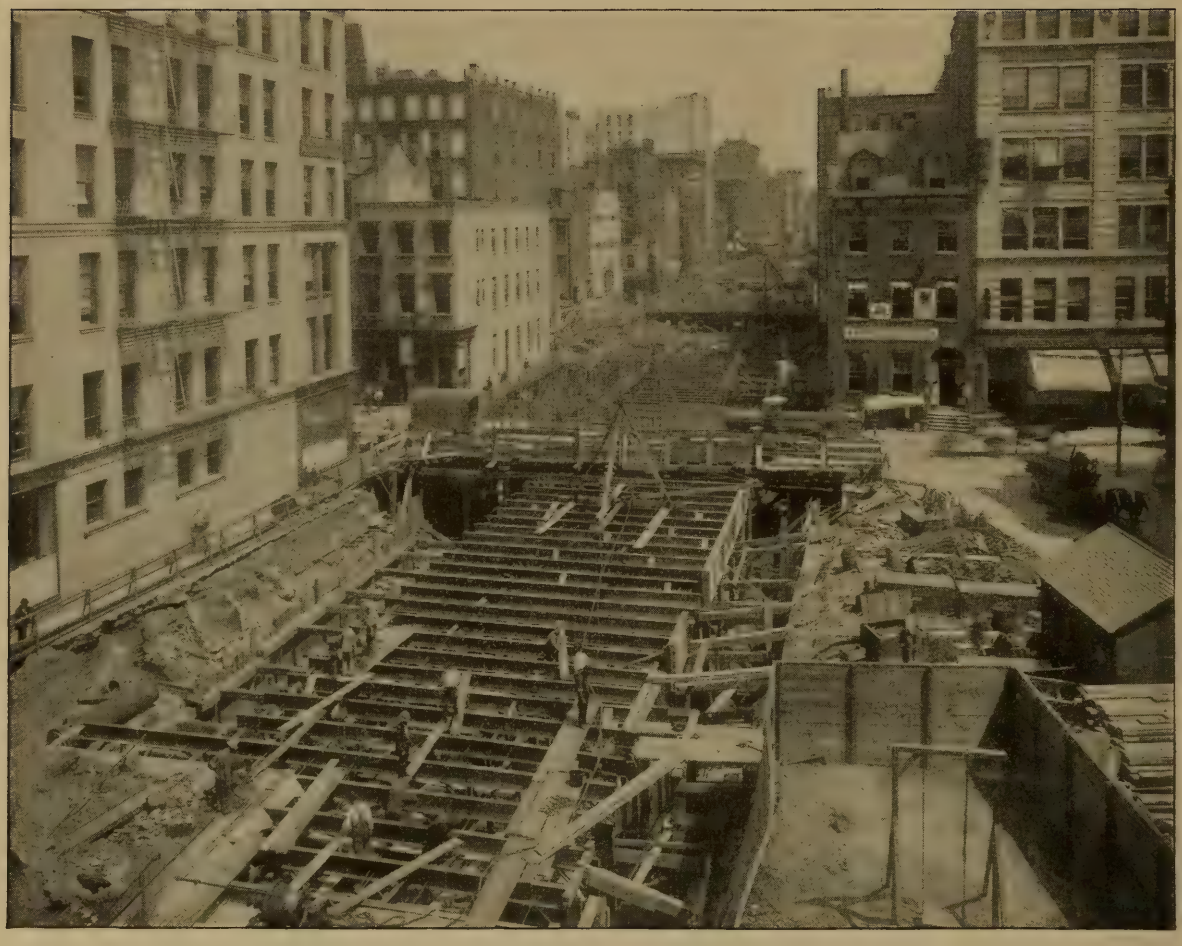
REAR VIEW OF TRINITY CHURCH, WITH THE MANHATTAN BUILDING AT THE RIGHT. HEIGHT TO TOP OF ROOF, 246 FEET. HEIGHT TO TOP OF TOWER, 348 FEET. SEVENTEEN STORIES. HEIGHT OF CHURCH STEEPLE, 284 FEET



A VIEW OF ONE PART OF THE RAPID TRANSIT SUBWAY WORK NOW IN PROGRESS IN NEW YORK

greatest cantilever structures in the world. This bridge will cross from Manhattan to Blackwell's Island, in the middle of the stream, and thence to Astoria, Long Island, on the other shore. There will be six piers to this bridge, the minimum cost is estimated at $8,000,000, and it will take about five years to complete the work. This structure, like the other ones, will not in any way interfere with the water traffic of the river, for it will swing far up above the highest funnel of steamboat or mast of sail ship that passes through Long Island Sound to take the sea beyond.

The third East River suspension bridge has already been planned, and may within a short time be constructed. This will cross the river not far from the other two, and is expected to cost about $10,000,000. Like the new one now nearing completion, it will have towers of steel instead of stone. Besides these several bridges the Long Island Railroad Company owns the franchise and plans for still another bridge across the river at its upper end to a point within the borough of the Bronx. This will complete the now contemplated network of overhead connections of Manhattan with the rest of the world on the East River side.

On the opposite side, where flows the broad Hudson, the work of crossing is more difficult, with engineering problems full of perplexities that make progress slow. There are at present two bridges under consideration, both of which have been approved by the United States War Department, and which may be commenced at any time. The Pennsylvania Railroad Company's bridge, one of the proposed structures, would be essentially a railroad bridge if built by that corporation, but it would also accommodate foot passengers. The other bridge was projected to cross

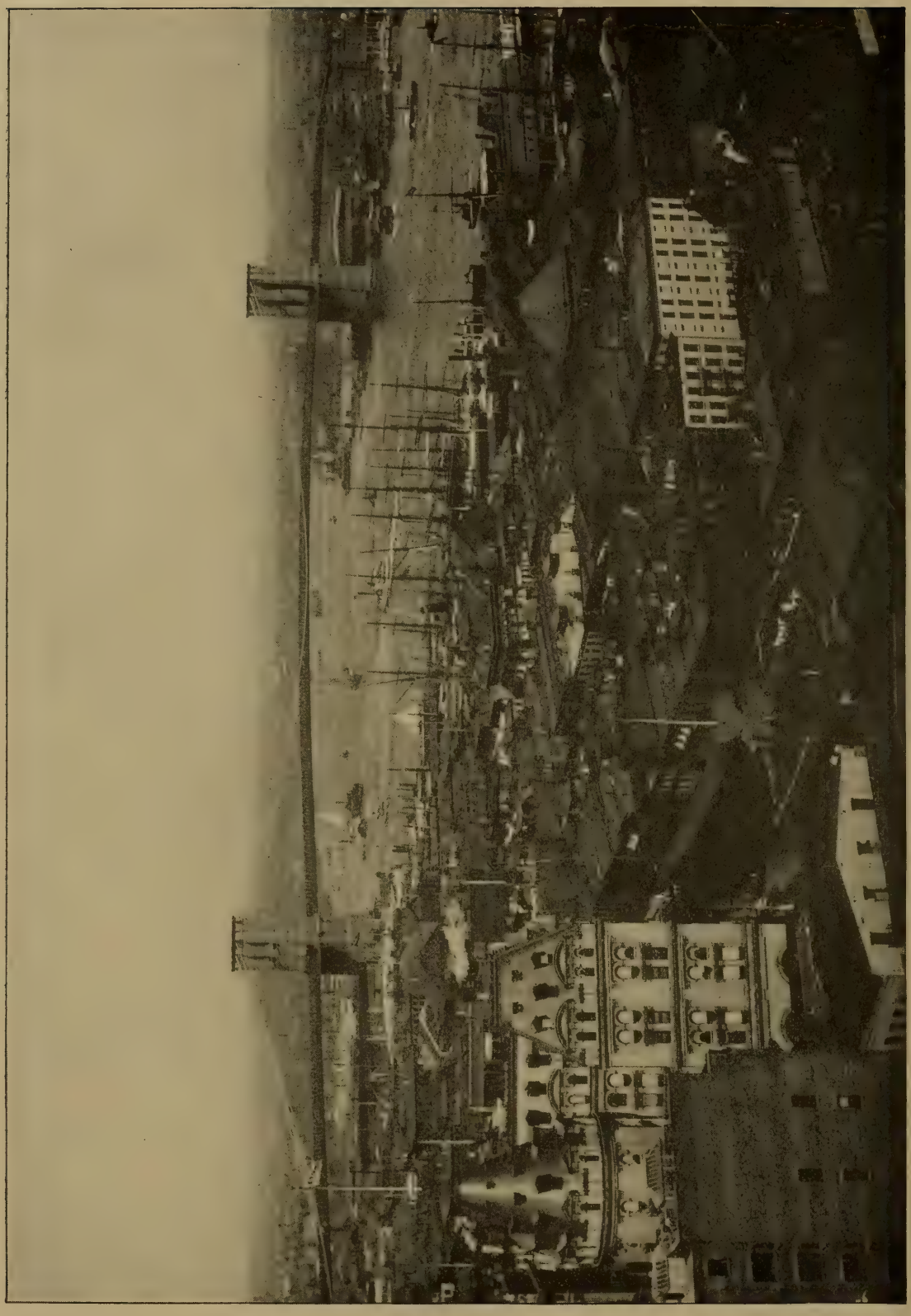
from Fifty-ninth street to Weehawken, on the Jersey shore. Either of these immense bridges would cost upwards of fifty and sixty million dollars.

The tunnel under the Hudson will be held in abeyance until engineering conditions more fully warrant its construction. If tunnels follow bridges, in due time it may be that the Hudson River will in the next decade flow over one of the most important tunnels in the world. There seems to be a consensus of opinion among experts that there would be little gained in bringing the freight traffic for distribution directly into the city, and the cost of building and maintaining a great railroad tunnel under the river would hardly be warranted for passenger traffic alone. Bridges could better accommodate passengers than tunnels.

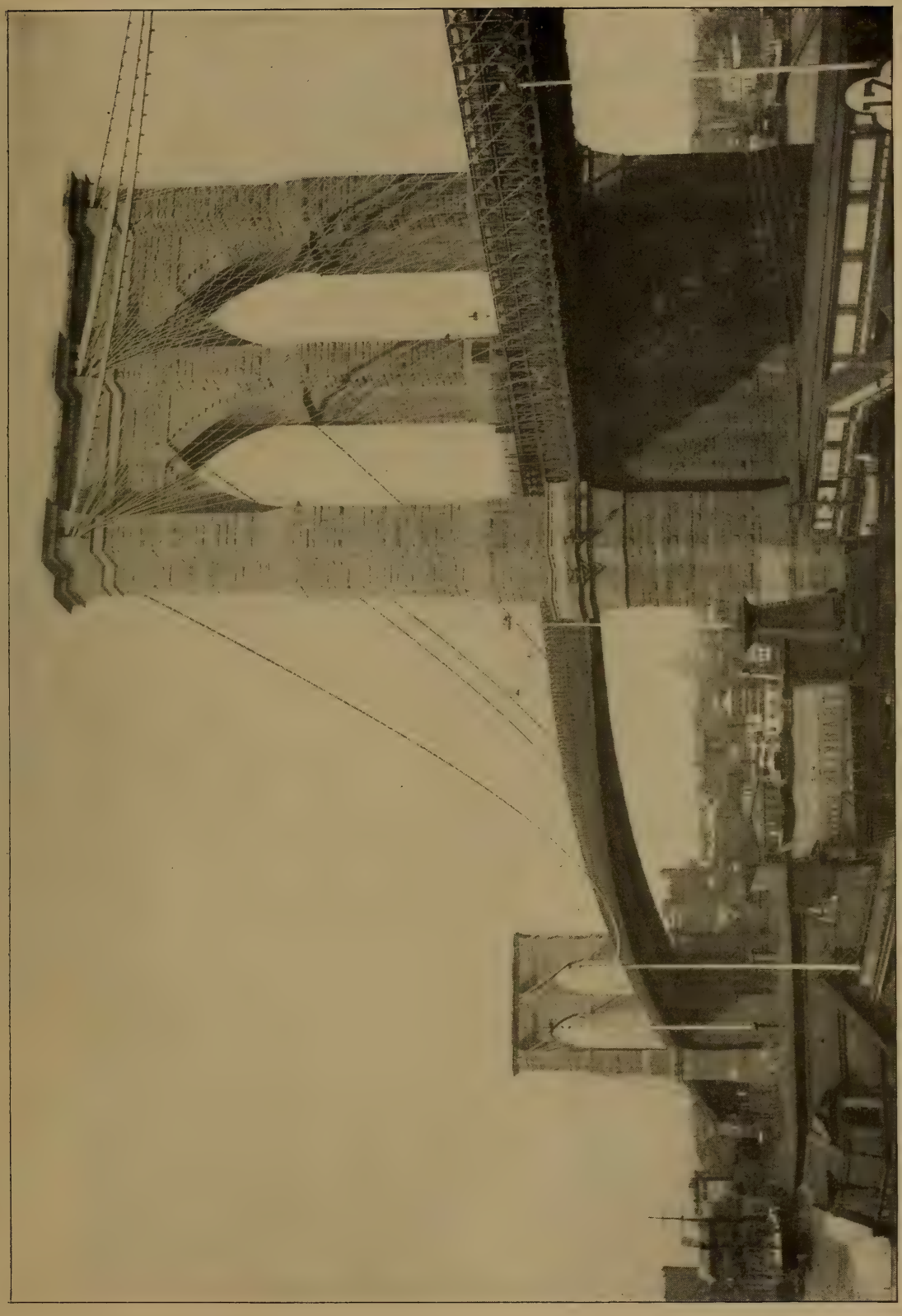
Nevertheless, the tunnel under the East River is practically an assured reality, and also a tunnel under the Narrows, guarding the entrance to upper New York Bay, to connect Staten Island with the Brooklyn shore. This latter would give to the Pennsylvania Railroad close connections with the city and a direct link in its proposed line to New England points. This project will greatly facilitate the freight traffic of the city, and transfer a good deal of the docking privileges from the Jersey to the Brooklyn shore. The easier distribution of freight and passengers from the West to points along the shore would make this scheme of tunneling the Narrows eminently practical and remunerative.

But the self-improvements of newer New York are not by any means limited to bridge and tunnel building. These are merely representative of the needs of the time, the outward signs that the city has outgrown its present proportions and is in need of more room. Up in the Bronx district millions of dollars are being lavishly spent to enhance the beauty and practical value of the city, and there, too, some engineering feats are in progress that may well be worth

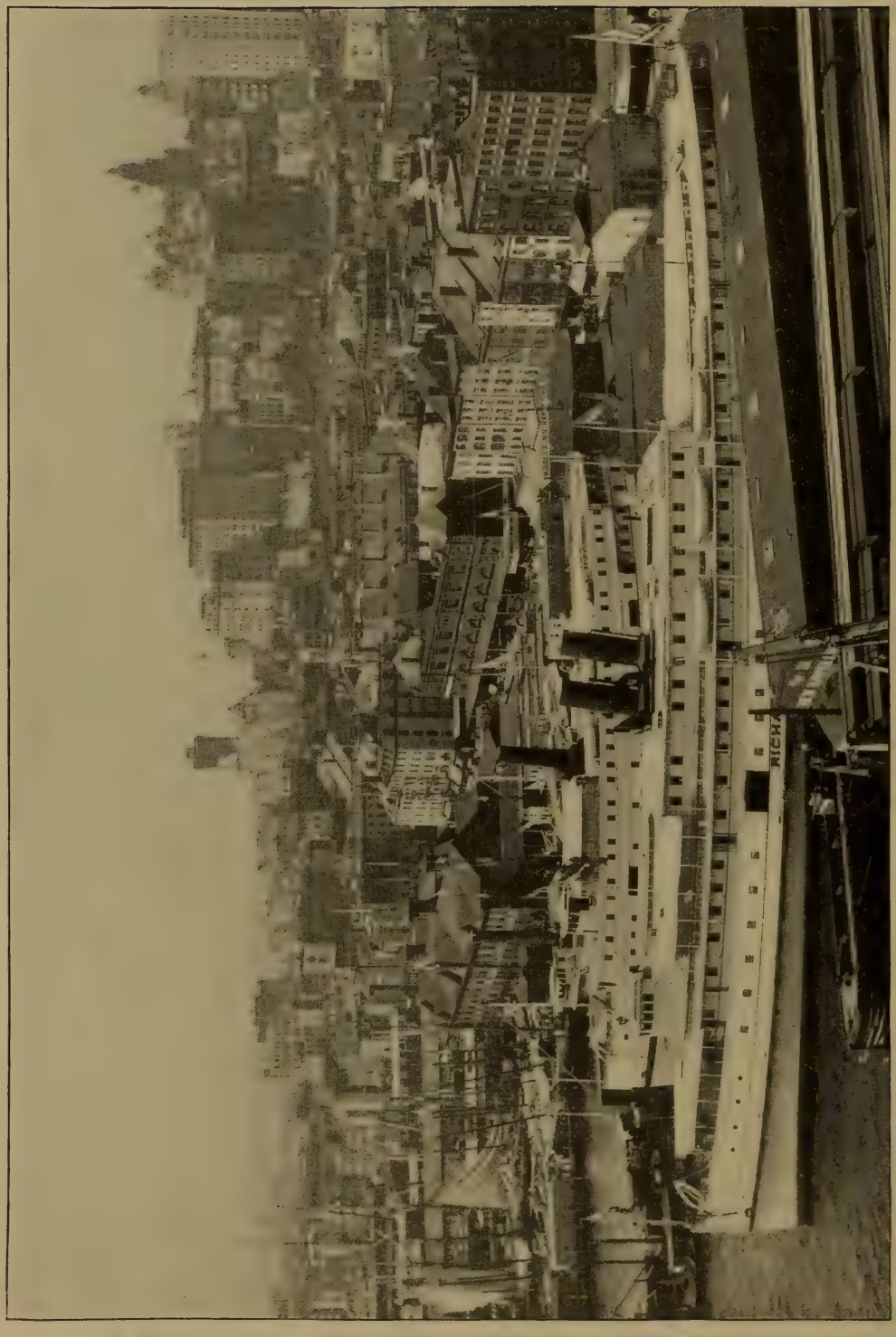
THE PRESENT CONDITION OF THE NEW BROOKLYN BRIDGE. MAIN SPAN, 1600 FEET. MINIMUM HEIGHT OF BRIDGE ABOVE MEAN HIGH WATER, 135 FEET. ESTIMATED COST, $12,000,000



THE OLD NEW YORK AND BROOKLYN SUSPENSION BRIDGE. LOOKING UP EAST RIVER



A NEARER VIEW. MAIN SPAN, 1595 FEET. CLEAR HEIGHT OF BRIDGE, IN CENTRE OF RIVER SPAN, ABOVE HIGH WATER, 135 FEET



THE DOCKS ALONG SOUTH STREET, ON EAST RIVER

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passing attention. The water supply of a great city is a question that needs urgent solution many years ahead of time, and New York has been none too early in the field in preparing its people with adequate reservoirs and piping systems for distribution of water. Indeed, more than once in the history of the city it seemed as if the increasing population would overtake the water supply and create a famine. Fortunately, by one means and another such a catastrophe has been averted. Sometimes it has been only by temporary makeshifts that the evil has been postponed, and more than once at a lavish use of money out of all proportions to the good obtained. In the building of cities to-day the water supply is considered one of the first essentials, and they prepare things differently from what they did years ago; but all this has been purchased through costly experience, and New York has contributed its full share of this experience, paying the price handsomely.

The new Jerome Park reservoir, when completed, will furnish an excellent water supply for the newer half of the city for many years to come. It has been in course of building now for three years, and it is only about half finished. About $15,000,000 will be ultimately expended on this reservoir so that the people of the upper part of the city can have all the water facilities they need. Thirty miles further north is the huge Cornell dam, which, when finished, will create a great inland sea of fresh water, storing for the city over 4,000,000,000 gallons. Millions of dollars must be spent on the Cornell dam before it will be completed, and with about five thousand workmen toiling there daily, it will take some time yet to finish the job.

The water front of New York is one of its most important commercial fea-

THE ELEVATED STEAM RAILWAY AND ELECTRIC SURFACE TRAMWAY ON THE BOWERY

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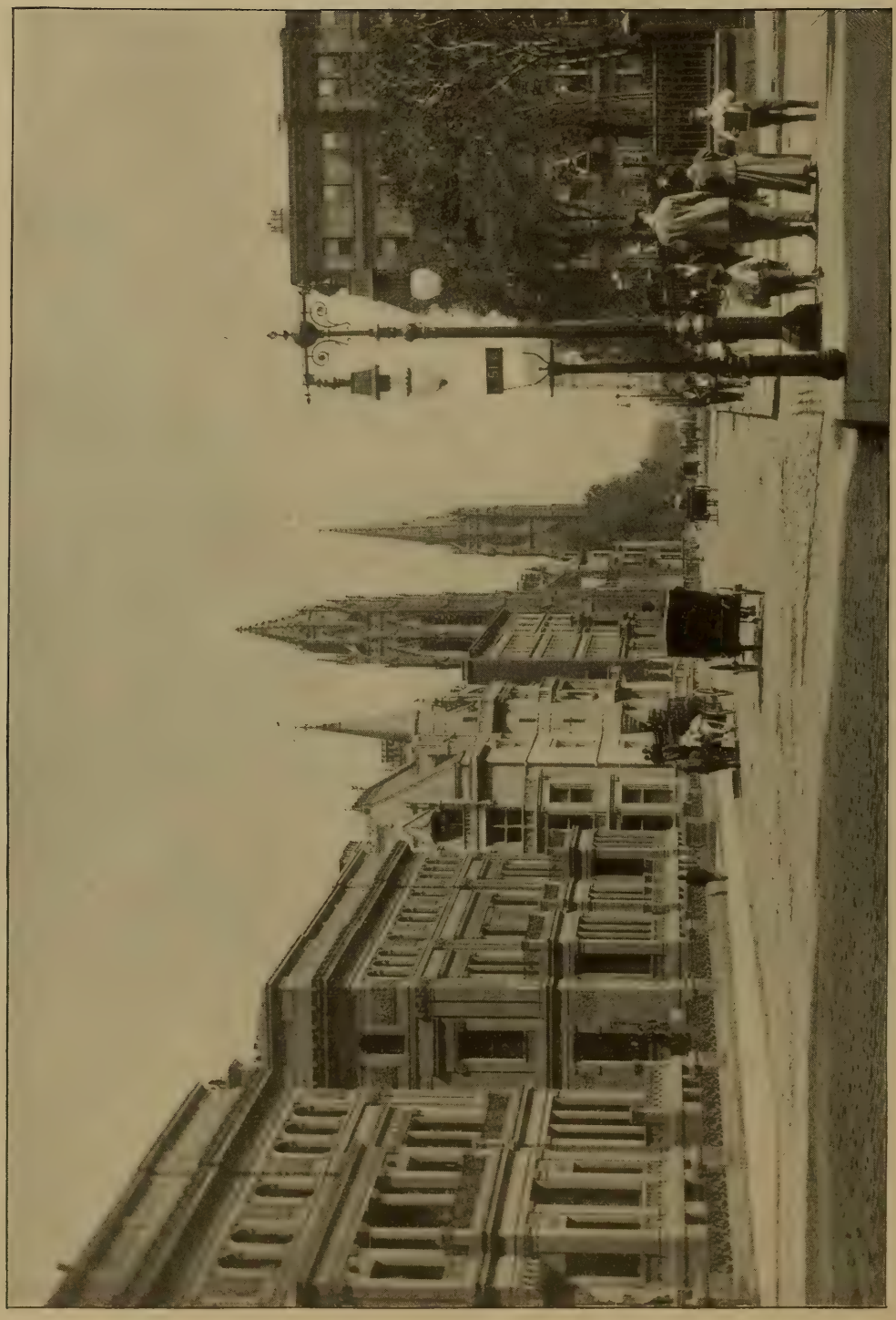

FIFTH AVENUE. THE RESIDENCE STREET OF NEW YORK'S WEALTH

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tures, but in respect to its docking arrangements the city has hardly kept pace with its marvelous growth in other directions. New and comprehensive dock systems are, however, now being built which will meet, better than ever before, the needs of its shipping interests. These dock improvements will cost the city several millions when finished. They will, however, for the first time give New York the full advantages of her natural docking facilities. There has been in the whole history of the city a noteworthy disregard of natural shipping facilities, which, in most European cities, would have long since been developed to the fullest possible extent, and it is a confirmation of the remarkable maritime situation and natural facilities of the town that New York's predominance and pre-eminence have been maintained in spite of these neglects. Indeed, her position as a great international seaport is the result of accident of birth and location more than that of careful planning and building. But in the new era of dock improvements it may be that some approach will be made to a standard of excellence in this respect which will partly compensate for past neglect. It is possible to make dock improvements which will place New York first among the great maritime cities of the world, and elaborate plans for such water front developments are now in slow process of evolution. On the Hudson River front ten new permanent piers to accommodate transatlantic trade are now in the course of building. The piers will be of stone and concrete, fireproof in the fullest sense of that word, 800 feet long, and 125 feet wide. They will be two stories high, and each structure will cost upward of $300,000, making the entire cost of the ten, $3,000,000. On the East River similar improvements of docks for the coast trade and railroad traffic are being pushed rapidly to completion, involving an expenditure of nearly two million dollars more. Eight new piers are being built there, 80 feet in width, and 425 feet long, which are considered of the proper size to accommodate the largest coasting steamers. The 800-foot piers on the Hudson River are expected to be of sufficient size to accommodate the largest ocean steamers for years to come; but should the rumoured 1000-foot steamers be built in the meanwhile, the city is prepared to add 200 feet more to these stone piers.

New piers on the Hudson River above One Hundred and Twenty-eighth street, and minor ones on the East River above Fiftieth street, are also being built, while new ferry slips are being constructed, so that there will be a complete revolution in the water front within the next few years. It will cost something like $8,000,000 to finish these dock, pier, and ferry improvements; but they will be of such modern and permanent character that they will for all time enhance the shipping interests of the city. The water front of New York has too long been an eyesore to home-coming men of business, and when the tumble-down wooden docks and crazy wooden sheds on the piers have all disappeared there will be rejoicing on all sides. No city in the world needs better and more commodious docking facilities than New York, and with the immense warehouses near by, the piers and sheds should be of the most non-combustible character. Conflagrations, such as visited the North German Lloyd docks, on the Jersey shore, a year ago, seem inexcusable; but the only sure prevention is to rebuild a good part of the piers and docks so that they will retard, rather than help, the spread of a fire.

Internal improvements of a great city are so varied in character that it is impossible to more than summarise most of them, for they must continue so long as a city is growing and developing. Parks and driveways must always attract a good deal of a city's annual appropriations for improvements, unless its people are so sordid in their ambitions that they will give little heed to embellishments, being contented with the merely practical, money-making side of municipal growth. New York in recent years has been exceptionally generous in its park expenditures, aton-

THE WALDORF-ASTORIA, THE LARGEST AND MOST SPLENDIDLY EQUIPPED HOTEL IN THE WORLD

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ing in a degree for its disregard of such matters in the past. Central Park continues to expand in beauty and attractiveness; but beyond merely maintaining the excellence of this great pleasure-ground, the expenditures for it are not great. Most of the park money in recent years has been diverted toward the improvement and establishment of smaller parks in the lower wards of the city, or in purchasing land for parks in the new wards of the Bronx district. Millions have been freely spent in this way in recent years. The small-park system inaugurated years ago has cost the city upward of $50,000,000. It requires millions of dollars merely to purchase the land for park purposes in the crowded portions of the city, but no municipal economist regrets the expenditure of such appropriations. A small park, to be established in what is known as "Little Italy," now the most crowded tenement district in the city, will cost over $5,000,000.

These small parks in the crowded

portions of the city should have been provided by the municipal government when the town was small, and for this lack of forethought the taxpayers now are paying dearly. Not to be thus handicapped in the future, the city is now lavishly providing its upper sections with park room and breathing places. The magnificent Bronx Park will eventually cost millions of dollars to develop, and, as planned now, large sums are annually appropriated for its maintenance.

Next to parks, beautiful drives and boulevards are most appreciated by the people of a city. The new driveway recently finished cost the city millions of dollars, and another one has already been planned for the Bronx section at an estimated cost of $12,000,000.

If one should enter into a description of the new buildings of a public nature now in course of construction by the city it would require considerable space merely to mention the details. The Museum of Natural History has been in progress for many years now, but when completed it will be one of the largest and handsomest structures in the world, covering five entire city blocks, and costing $13,000,000. The new public library building will be an expensive structure, costing upward of $8,000,000 when completed. The new Hall of Records, which the city is constructing down town, will cost over $4,000,000.

For self-improvement at the beginning of the twentieth century the city will thus have a bill to pay that will easily mount up to and beyond the $100,000,000 mark. If one includes in this the bridges and tunnels of a semi-public character, built under franchises granted by the city, the bill might easily be rounded out to the $200,000,000 limit. And in this nothing is said of the new Custom House building, the

ONE OF THE CITY'S BREATHING PLACES. THE MALL IN CENTRAL PARK

new Chamber of Commerce building, the great Episcopal Cathedral of St. John the Divine on Morningside Heights, or the new Columbia University buildings, or the great electric power plant of the Manhattan Elevated Railroad, and that of the Electric Light, Heat & Power Company, two of the largest power plants in the world, developing nearly 100,000 horse-power for electrical transmission. But as these do not properly come under the dominion of a city's self-improvements, a description of them is hardly in place here. Nevertheless, they will help to show the character of the gigantic and costly growth of New York far more than the private residences or many-storied sky-scrapers, both of which are more temporary in their indications. Likewise the enormous apartment houses, with their wonderful hotel-like conveniences and elaborate appointments, are the results of a fashion, which may or may not prove a permanent part of the city's growth.

VENTILATION OF BUILDINGS IN INDIA

AN OPPORTUNITY FOR AMERICAN ENTERPRISE

By John Wallace, C. E., Editor of the "Indian Municipal Journal," Bombay

THE supply of locomotives, rails, and bridges by America to India has been the subject of much bitter discussion in the Indian and Anglo-Indian press, so bitter that it has often ceased to be scientific. We have also been, more peaceably, invaded by the rolled steel beams of Mr. Carnegie, and the hardware of a number of manufacturers represented by the New York Export Agency, which appears to be doing a steadily increasing business. But there is another invasion that is much wanted, particularly in Bombay and Calcutta,—of housebuilders,—an invasion that would be received with open arms by the European community.

Bombay has belonged to Great Britain since 1661, but in all the interval the English people have been content to live in houses built for them and owned by natives. British capital furnished the railways that have proved of inestimable value to the country, but the return on the money invested was much too small to merit the attention of native capitalists. House property returns from 4 to 30 per cent. per annum, the lowest figure being the profit on bungalows with gardens, and the highest that of the overcrowded habitations of the poorest class. House property is an exceedingly popular investment among the wealthy natives, and as every one of them seems to think that the possession of money brings with it a talent for designing dwellings, the buildings are mostly unsatisfactory, both as regards the division of space and as regards ventilation, the latter being especially defective. Large and lofty rooms are now too expensive for any but the wealthiest people, on account of the high price of land, and blocks of buildings, which are now in fashion, have so much mass that they are properly ventilated only when a breeze is blowing. This amounts to saying that the air in them is often quite stagnant on account of the frequent periods of calm on an island whose mean annual wind velocity scarcely exceeds twelve miles an hour.

Most of the new houses have a fine show of windows on the outside, but no corresponding opening to allow a current of air to pass through. The mean annual temperature is 79.13° Fahr., and the mean relative humidity

77 per cent. The mean annual range of temperature is 46.9°, but there are periods during the rains when the diurnal range of temperature does not exceed 2 degrees, and, unless there is wind, ventilation is practically stopped because the outer air and that in the buildings are reduced to nearly one temperature. With the thermometer at 82 to 84° and the air heavily charged with moisture, the surplus heat of the human body escapes very slowly, and much discomfort ensues. As it is not possible to dry the air in an ordinary house, the usual remedy is to produce a current by means of a punkah, and although the influence of this is very local, it has been found that in the worst Bombay weather life is made tolerable in its current. The chief drawback of the punkah is the punkahwalla. He is dirty, unreliable, especially at night, and his work, counting day and night, costs twenty-four rupees per month for a single punkah.

The functions of respiration and the escape of surplus heat must be uniform and regular in order to ensure health and comfort, and as the structure of the Bombay house renders effective ventilation impossible, there is no choice but to call in the aid of science for the supply of fresh air, just as water, gas, and electrical current are already supplied in most cities. Every year, in the dry season, camps are established in parks and open spaces about Bombay to accommodate an excess of population which finds life under canvas, with its many drawbacks, preferable to life in houses which are badly arranged and often unwholesome. The tents are stored for seven months in order to be used for five, and this annual camp is an annual proof of insufficient house accommodation. Various projects have been discussed with a view to providing suitable houses for the European population, but nothing, so far, has come of them, and the need for wholesome houses is, if possible, greater than ever.

There is an excellent climate which is very near Bombay, measuring vertically. It lies within a hundred feet of the surface, and is free from all the dust and smells that are too much in evidence at the ground level, and even, at times, in the third story. What we Europeans want is to live in that climate, and as it will not pay to climb up to it, we want it brought down so that every story in our dwellings may be filled with uncontaminated air, even if it should be a basement story. This system of ventilation resembles that of a coal mine, only that the air will escape below. It involves no change in the outward appearance of a house, but it will ensure a constant change of air, at a rate under perfect control, corresponding with the constant needs of the human system. A building, fitted with a silent engine and a ventilating fan on the roof, would have to be large enough to bear the cost of the machinery and a competent agent or manager; on the other hand, rooms of every size would be equally wholesome and comfortable in all weathers, as the renewal of the air supply would no longer depend on chance.

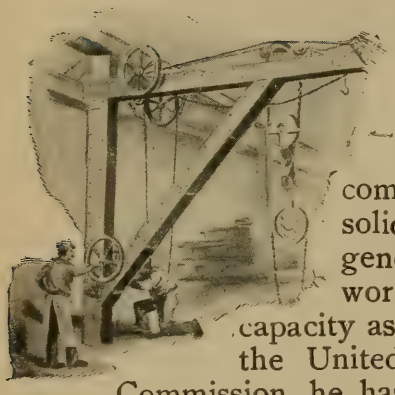
It has been observed that at about 80 feet from the ground in Bombay there are no flies of any kind,—probably because the air at that height contains nothing for them to eat. An air supply taken at 100 feet from the ground would introduce new and beneficial influences into domestic life, ensuring the most healthy condition both by day and night. The construction of such buildings would differ in some respects from anything that has hitherto been done, but it would be simpler than many installations, as it would be complicated with neither heating nor cooling apparatus. The motor would be suited for driving a dynamo as well as a fan, as the resistance of each would be of the same character, so that lighting and ventilating could, if desired, be effected by the same machine. The prospects of a public supply of electricity in Bombay are still remote.

Americans with a taste for new enterprises and for Eastern travel might do worse than inquire, next cold season, into the defects of the housing accommodation of Bombay.

TRADE COMBINATIONS

IN GREAT BRITAIN AND ON THE CONTINENT

A Report by J. W. Jenks, of the United States Industrial Commission



WHAT Professor Jenks does not know about industrial combinations and consolidations is believed generally to be not worth knowing. In his capacity as "trust" expert of the United States Industrial Commission, he has prepared an elaborate report upon the subject of European "trusts," based upon an exhaustive investigation extending over the past two years, and embracing visits to the leading industrial centres of Great Britain and the Continent. Of this report an official abstract has been prepared by the Industrial Commission, whose conclusions, by the way, of special interest at this time as bearing upon similar problems in the United States, are that there is little objection to combinations in Europe; that there is little or no belief that the protective tariff is responsible for their existence; that there are no railway discriminations in Europe tending to create combinations; that the publicity in the organisation of corporations there has largely prevented stock watering, and that there is no inclination manifested in the leading European countries toward the passage of laws designed to kill the combinations. The commission's summary is as follows:—

The situation regarding industrial combinations in Europe probably justifies the following conclusions regarding the nature and results of industrial combinations there, and European experience suggests certain thoughts applicable to the situation in the United States.

There is a strong tendency toward the formation of industrial combinations everywhere in Europe. In Germany it is probable that the movement has extended as far as in the United States, and that the combinations there, speaking generally, exert as great power over prices, over wages, and in other directions as they do in America. The plan of organisation, however, is materially different. In most cases the German combinations are made simply by contracts between independent establishments regarding output, prices, etc., instead of the form being that of a single large corporation. In practically all of the important cases, however, the central control, owing to the favourable attitude of the German Government, and law courts, and public opinion, is complete to give full power of direction.

In Austria the situation is nearly the same, so far as the extent and power of the combinations are concerned. On the other hand, there is more disapproval of the combinations on the part of the public, and three decisions of the courts made within the last three years, which render the contracts among the different parties to the combination non-enforceable, seem to have weakened in many respects the strength of the combinations within themselves. So far, these decisions have produced little effect, but it is practically certain that if this attitude of the courts is not changed, and if there is no new legislation, the combinations will be likely to take on a new form in certain particulars.

In Great Britain the movement toward combination has not gone so far as in either Austria or Germany. There have been in earlier days very many

local combinations to keep up prices, and in some cases these combinations have proved very successful. Within the last three years, however, a very active movement toward the concentration of industry into large single corporations, quite after the form which has been common in the United States, may be observed. Nearly all of the feeling that one observes in Great Britain on this subject has reference to the later great corporations formed by the buying up of many different establishments in the same line of business, corporations that, through combination, have succeeded in acquiring in many particulars a good degree of monopolistic control.

In France one finds the movement toward combination much less pronounced than in any of the countries mentioned before. The reasons for this are, perhaps, two in number:—First. France is less developed industrially than the other three countries, especially England and Germany, and as French industry has not yet entered so much into international competition as have business men in other countries, the same pressure toward the savings and toward the added power that came from combination has not been felt. In the second place, the French criminal code is very severe against fraudulent or monopolistic attempts to control the market. This code was doubtless passed with reference to conditions entirely different from those now existing, but if a combination should apparently be able to increase prices, and should attempt to do so, its officers might be in danger of imprisonment. In consequence, while the movement toward combination is very evident, the managers of combinations are much less inclined to let their movements appear in public. It is also true beyond question that the combinations in France, with few exceptions, are less firm in their method of organisation, much more being dependent upon mere verbal agreements.

The form which the combinations take in every country seems to be partly a result of the business habits of the country, partly a result of legislation or lack of legislation.

In practically all places the combinations start by simple agreements among different establishments to sell at a uniform price, or to make no effort to secure the patronage of the customers of one another, or,—another manifestation of the same plan,—to divide territory among themselves. In most instances, particularly if there are many members of the combination, it will be found that some are not faithfully living up to their agreements, and an effort is then made to secure a firmer union. Wherever the courts will hold an agreement for limiting production or uniform prices legal, the more natural and usual form is for the contracts to be put into writing, with a penalty for breach of contract.

In order to avoid the necessity of litigation it is very common for deposits of securities to be made by each participant of the agreement, with the understanding that if the contract is violated the deposit will be forfeited. If the laws of the country, however, as enforced by the courts, hold such contracts illegal and contrary to public policy, so that they cannot be enforced, the combinations are practically compelled to take some other form, such as that of a single corporation, as in the United States and of late in Great Britain, or else to accomplish the same result in some other way. If the agreement has to do particularly with the regulation of price and is not intended to affect materially the methods of manufacture, it is a common practice in France, in Germany, and in Austria, as well as in other European countries, to organise a selling bureau for all of the establishments, and through the selling bureau, which in itself may be a separate corporation, to determine the extent of the output for each separate establishment and the price that shall be secured for goods. In such cases, of course, the books of the separate members of the combination are open to the selling bureau, and the work of the bureau is open to all of the members, so as to prevent fraud of every kind.

On the Continent of Europe it is very generally the case that these combinations regarding prices and output refer only to goods sold within the country, and do not apply to sales for export. It is possible to determine with a reasonable degree of exactness the quantity of goods of any kind that will be consumed at a price remunerative to the combinations within the country itself; that quantity is then fixed, and a steady, uniform price for the whole country may practically be established at rates not very oppressive to the consumers and at the same time profitable to the combination. Any additional spirit of enterprise on the part of any of the members has to seek its satisfaction in foreign trade.

In practically all of the countries the causes for combination are substantially the same as those found in the United States. The first motive usually assigned is ruinous competition carried to so great an extent that practically all are losing money.

The desire for increasing profits, of course, is also satisfied more easily when great economies can be made, and it is generally found that by a combination savings of various sorts can be secured. It is to be noted, however, that in Austria, France, and Germany, where the form of combination is largely that of simple agreements among different establishments, each one of which is managed independently, the savings that come from closing of the poorest establishments, from the better distribution of products among different establishments, etc., cannot well be secured, although those which come from lessened cost of selling are easily made. Members of syndicates in the cases mentioned do not hesitate to acknowledge that the form of combination into a single corporation is more advantageous in this respect than the form that is more common in their own country. They, however, attribute their hesitation to adopt the more complete form to the high taxation and the publicity to which corporations are subjected, and to the greater spirit of independence, as they claim, on the part of their manufacturers, who, they say, would not be willing to give up the power of independent management of their own establishments. It is probable, however, that they have not yet felt the pressure of necessity to so great an extent as has been the case with manufacturers in Great Britain and the United States on account of the unwillingness of the courts in those countries to enforce contracts that seem to be in restraint of trade.

Industrial combinations seem to have been made throughout Europe with practically no aid through discriminating rates given by the railways or other transportation agencies. It is true that in practically all countries at times special rates have been given to foster some special industry in certain sections of the country. Particularly is this true where the railways are owned by the government, as in Prussia; but even there no discrimination is made between different shippers under similar conditions, and the rate is given rather as a bounty to encourage the development of the industry or to increase the export trade, instead of a certain amount paid out of the public treasury, as in several of the States of America, for example, to foster the beet sugar industry. It is possible that in one or two of the countries there have been slight discriminations made in individual cases, but this has been done so rarely that it may be said to be of no significance whatever.

Protective tariffs do not seem to have been of special significance in the formation of industrial combinations on the Continent, although in many cases the combination has been enabled to take advantage of the protective tariff in the way of securing higher prices. In free trade Great Britain the combination movement seems to have developed considerably further than in protectionist France; but, on the other hand, the movement toward combination has gone much further in extent in Austria and Germany, both protectionist countries, than in Great Britain, although in Great Britain the form of combination is generally more complete. Dr. Liefmann, in an article on combinations in Great

Britain, expresses the opinion that the chief reason for the lesser development of monopolistic combinations there and the continuance of severe competition in branches of industry in which in Germany there have existed for a long time very rigid combinations,—for example, the coal industry,—ascribes the cause rather to the principle of extreme individualism in Great Britain which has a much firmer hold among business men, in his judgment, than in Germany; and this appears, on the whole, to be the right conception.

On the other hand, there can be no doubt that the combinations at times make use of the tariff. In France, Germany, and Austria the tariffs seem, in general, to have been levied with the idea of furnishing a sufficient protection against foreign competition without placing them much higher than was necessary to cover the normal difference in cost of production. The governments seem inclined to stand firmly by their protective policy, and there seems to be no very active propaganda hostile to it. In consequence the combinations have no fear of the tariff being removed and their industry killed by foreign competition. The manufacturers, therefore, who are combined, as well as those who are outside of the combinations, expect, as they say, to use the advantage that has been given them by their Government as against foreign competitors. Herr Wittgenstein, the chief spirit in the organisation and management of the Austrian iron combination, said a year or so ago that the Government having recognised the need of the iron industry for a tariff, had levied it. The combination intended to meet these expectations by putting their prices as high as the tariff would, under ordinary circumstances, permit. Director Kestranek, of the same combination, takes the same position. But he goes further and urges that the Austrian Government ought to place its tariff rates still higher, so as to guard against attacks on the Austrian market by American combinations favoured by their tariff. The competitive power of the foreigner, and not merely the difference in cost of production, ought to be the measure of the amount of protection needed.

One of the directors of the oil combination in Austria said lately, in the same frank way, that without their protective tariff the Standard Oil Company could probably drive them entirely out of business in Austria. The Government would certainly not permit their industry to be so ruined. With the protective tariff they placed their prices at such a rate that they were sure of making a fair profit in Austria; and, being secure of this profit, they had been able to make so much trouble for the Standard Oil Company in Germany and elsewhere that they had compelled that company to divide the markets, not merely of Germany, but also of two or three other countries, with them,—a procedure which, he claimed, was to the advantage of Austria, inasmuch as it was making the Austrian oil industry more profitable than it could otherwise have been.

Likewise the managing director of one of the great iron combinations in France has stated that, if you wish to get his course of prices over a series of years, the simplest way is to take the British trade papers, get the London price of iron of similar grade throughout the period, and add to that the freight from Great Britain and the French tariff.

It should be noted in all of these cases that the manufacturers believed that without their tariff their entire industry would be ruined by foreign competition; that their tariff was in itself not unreasonable and did not permit them to take from their home consumers unreasonable profits; that, however, it did enable them to be perfectly sure of good profits and at times enabled them, in consequence, to enter foreign markets by making low prices there. In all of the cases it is probable that after the combination was made, they could have stood some lowering of their tariff, and in consequence some lowering of their profits, without being driven out of business; but it seems also probable that in nearly all cases when in those countries protection is granted, an entire removal

of the tariff would have curtailed, if it had not completely ruined, their business.

It has been said that in certain cases it is probable that the desire to protect themselves somewhat against the attacks of the trade unions has been a reason why manufacturers have entered into combinations. On the other hand, it does not seem to be the case that any reduction in wages, speaking generally, has followed their organisation, although in certain instances, as in that of traveling salesmen, the combinations have been able to dispense with the services of some workmen. Often, since the combinations have been formed, wages have been increased. In other cases wages throughout the different branches of the industry have been made more nearly uniform than they were while the establishments were under different managements; and generally, so far as one is able to learn, the process has been one rather of leveling up than of leveling down.

It is claimed also, notably, perhaps, in the case of the coal and iron industries in Continental Europe, that combination has helped to secure a much steadier output than was possible before the combinations were made. In consequence, the number of workingmen employed has remained much more nearly uniform and their employment much more nearly continuous than before. It may be that during times of special prosperity under the old system more mines would be opened and more men would be employed temporarily, only to be thrown out of employment completely whenever the demand slackened somewhat. During the last two years of prosperity, however, the German coal syndicate have increased their output more rapidly than their rivals have increased theirs. The managers of the combinations claim that their purpose is to keep their business steady, free, as far as possible, from the fluctuations which often arise under a competing system, and, in consequence, to secure for their workingmen much steadier employment at uniform wages. The results, in the one or two industries mentioned at any rate, seem to show that they have, to a considerable extent, realised their expectations; and although there have been some complaints, on the whole the workingmen seem to agree that these results have been attained. So far as can be learned, too, the leaders of some powerful unions have been, in the main, working in harmony with the managers of the combinations.

Under other headings the subject of prices has been somewhat discussed. It will, perhaps, suffice to say here that the managers of the combination acknowledge that in many instances they have been enabled to secure prices somewhat higher than was possible under the system of ruinous competition which prevailed before the combination was made. Generally they claim that their prices have been more uniform than before. The managers of the coal syndicate in Western Germany say, for example, that during the period of the strongest demand for coal during the last two years, judging from earlier experience, they have held prices far lower than would have been the case under a system of free competition, believing that this policy was, in the long run, a wiser one. This plan would tend to prevent any crisis in the industry, with a corresponding depression following. In other lines of industry similar claims are made. Uniformity of prices or rates affording a secure profit seems to be the end sought for throughout Europe, openly avowed, and, to a reasonable extent, attained. While there are certain savings which might possibly justify a reduction of price, these do not seem to be emphasised so much on the Continent as in either Great Britain or the United States, nor are claims of reduction in price so frequent.

As in the United States, so elsewhere, complaints are frequently heard that the combinations sell for export at rates lower than domestic. The combinations do not deny the charge. They claim that they must do so if they are to export at all, and that the export business is necessary to keep their works running full time and their labourers em-

ployed. When the governments grant export bounties and the government railways grant special low rates on export goods, we might expect that they would make no effort to conceal their low export price. Indeed, some of the combinations themselves give premiums on their goods exported.

Industrial combinations do not seem to have awakened the hostility in any country that is met with in the United States. In Great Britain one finds in the papers a little expression of fear of the newer large syndicates. The government has taken no action whatever regarding them further than to pass, August 8, 1900, an amendment to the Companies Act, which provides for greater publicity regarding the promotion and the annual business of corporations than before.

In France there has been some complaint, especially against what is believed to be a combination on the part of the sugar refiners, but no general public movement. One or two cases, in the porcelain industry for one, have been brought by competitors against the syndicates, but the decision of the judiciary was simply no cause for action. The complainant did not show any increase in price, and the fact that a decrease in price was likely to drive the complainant out of business did not seem to the government a public menace.

In Austria, as has been said before, the courts have held that under a law of 1870 contracts for fixing prices were contrary to the public interest and were non-enforceable. There has been also much greater alarm apparently on the part of the public than in either Great Britain or France. Inquiries into the movement have been made by several chambers of commerce, notably those of Vienna and Prague. The government instituted an inquiry some years ago, and in 1897 introduced a bill providing for satisfactory investigation and limitation of the action of these corporations in the sugar, petroleum, beer, and spirits industries. The immediate cause of this movement was a financial one, the fear that these combinations, by raising prices, would lessen the consumption of the product, and thereby lessen the internal revenue tax which would be received by the treasury. The bill, however, was not passed. There is at present an inquiry on foot in the department of trade and commerce in Vienna. The committee investigating the question has reached two conclusions:—First, the combinations should be recognised as juristic persons; and, second, they should be put under State control, with a good degree of publicity.

They have, however, not decided exactly what the nature of this control should be. In the bill introduced in 1897 the remedy for proved monopoly was to be merely complete publicity, though some power was given the ministry to forbid certain contracts in exceptional cases.

In Germany, where the movement has existed for a good many years and has been carried very far, there seems to be little popular sentiment against the combinations, as a rule, but in certain localities there has been some activity. For example, during the last two years, since the price of coal has been high and the coal syndicate has refused to fill the orders of many manufacturers, much complaint has been heard and one or two inquiries have been set on foot by the chambers of commerce, particularly the Chamber of Commerce of Cologne. The coal syndicate claimed, as has been intimated, that they were furnishing all the coal that was needed for manufacturing purposes, but that the manufacturers wished to secure larger quantities for speculative purposes, and this did not seem to them to justify the opening of new mines, which would be a source of loss to them as soon as the extraordinary demand ceased. As a consequence presumably of this feeling, the governments both of Prussia and of the German Empire have set on foot inquiries in their executive departments into this subject. They are collecting literature within the country and from foreign countries, and will possibly later make a more immediate inquiry on the ground.

On December 6, 1900, there was in-

troduced into the Reichstag a resolution requesting the Imperial Chancellor to introduce a bill providing for governmental supervision over such combinations and syndicates as were shown to have assumed a monopolistic character. In response to a somewhat similar suggestion, made in the spring of 1899, the Prussian Minister for Trade and Industries took the position, in a speech in the House of Representatives, that the high price of coal was, under the circumstances, a normal one, and that there was no reason for complaint. He even went so far as to say that up to that time, at any rate, he thought that no one had any ground for making any objections to the working of the syndicates. On the contrary, he declared that they had, in general, contributed toward making the course of prices, as well as that of wages, even more steady than they had been in earlier times, and added that he was convinced that if the syndicates did not exist they would have been much more severe upon industry and upon consumers, as well as upon wage-earners. He took similar ground in the Reichstag and was supported by the other ministers.

The courts of Germany have taken the position that these agreements regarding output and prices, sanctioned by a penalty in order to check ruinous competition, are enforceable.

The legislation on the subject has already been indicated in part. In France the penal code provides a penalty of imprisonment and fine for coalition to raise or lower prices. This provision was, of course, made in earlier days, and was not intended to be against modern syndicates, although it is believed that it would apply to them in certain instances.

No other country has any special provisions against syndicates. In Great Britain the corporation laws, as already explained, provide for a great degree of publicity in connection with promotion of corporations and their regular management.

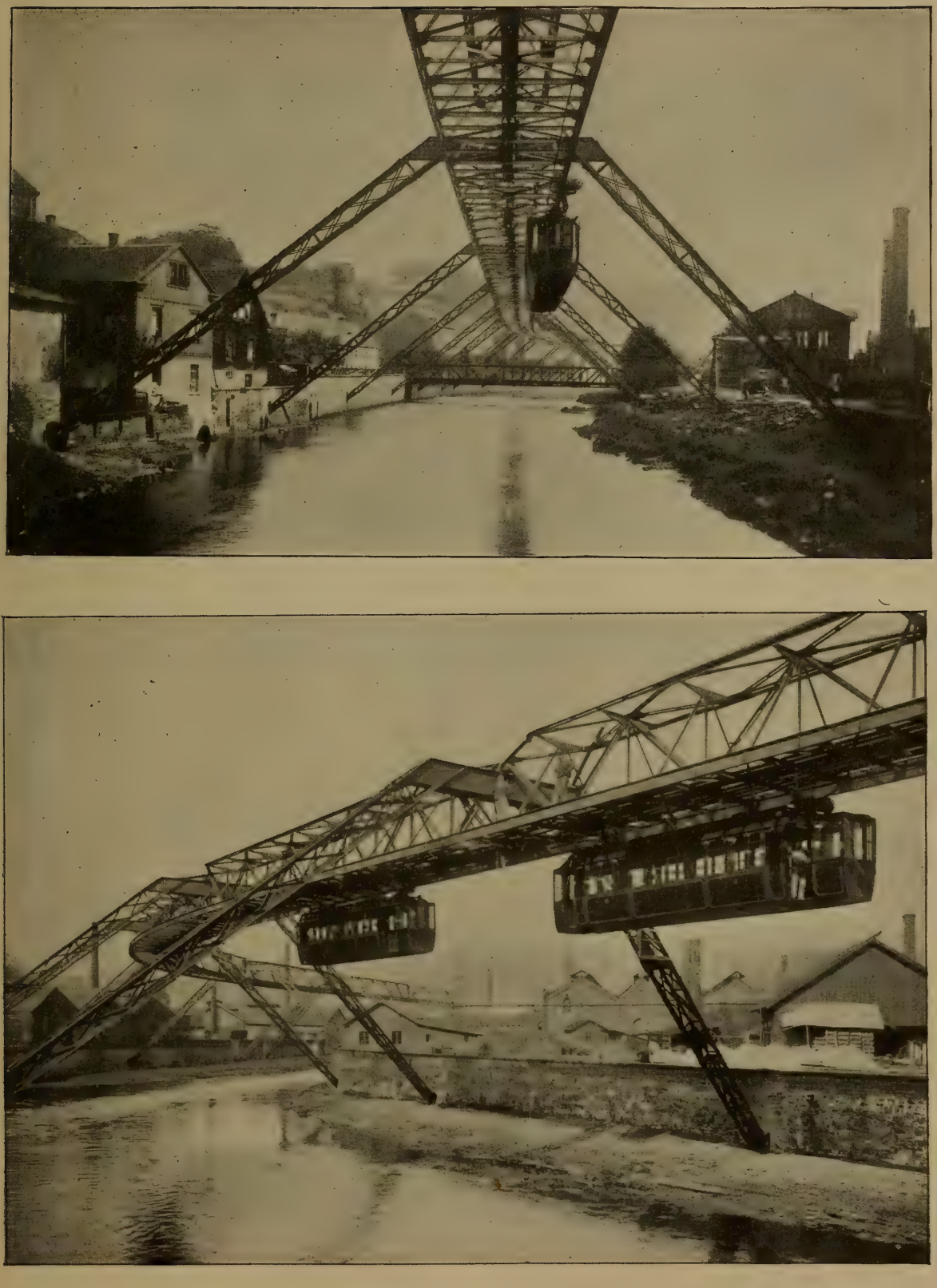
There is a like degree of publicity for corporations in France, Germany and Austria, and in these latter countries there are such rigid provisions regarding the valuation of property, and reports of promoters and directors, that stock watering, in the ordinary sense of the expression as used in the United States, is almost, if not quite, an impossibility.

A GERMAN SUSPENSION RAILWAY

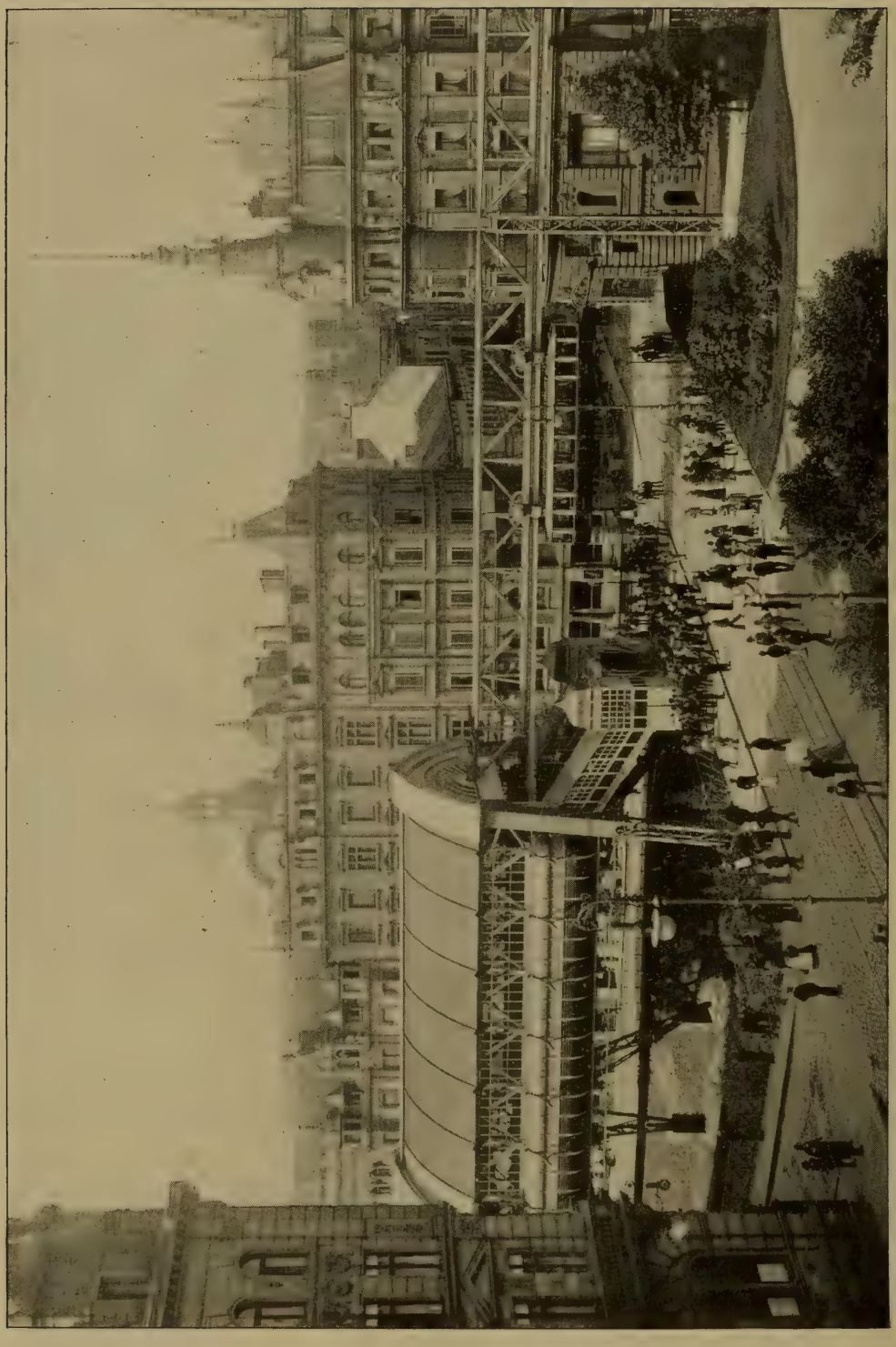
By Ronald L. Pearse

SOMEWHAT over half a dozen years ago one of the popular magazines published an illustration which it titled "The Tram of a Century Hence," and which showed a tramcar body suspended from running gear on an overhead rail structure instead of resting upon it in the conventional way. The picture was intended to portray an ideal system of transportation to be developed by some genius of the future, but its author clearly was unmindful of the fact that practical application of the principle involved had been made years ago, and was to be found in many engineering workshops in the shape of the familiar overhead trolley-rail for carrying heavy pieces of machinery or structural work from one point to another.

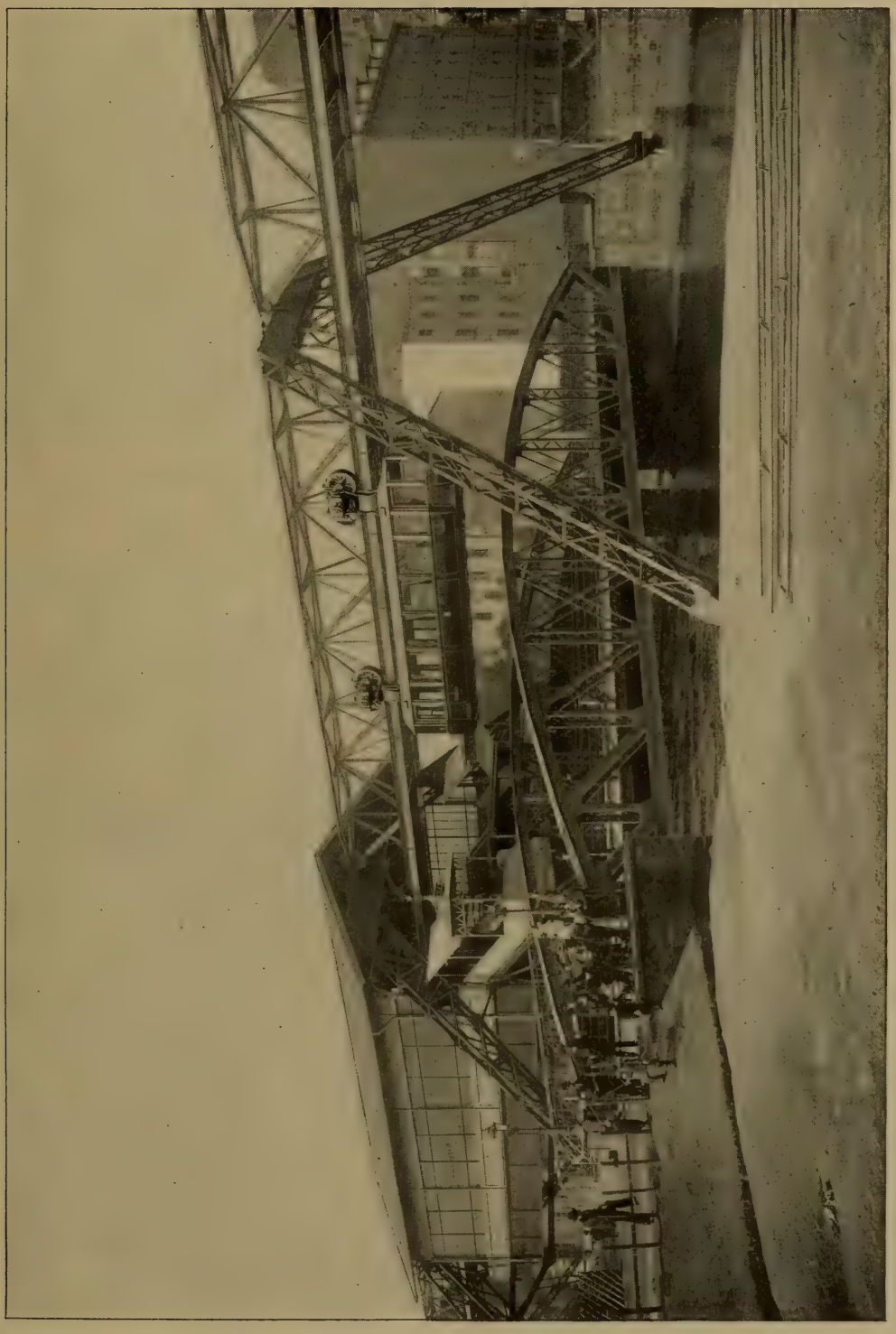
Eugen Langen, a German engineer at Cologne, had, moreover, at that time already worked out plans for what he called a suspension railway, utilising the above principle, and the building of such a line, to connect the German towns of Barmen and Elberfeld, was seriously talked of, so that the "tram



THE LINE ABOVE THE WUPPER RIVER NEAR ELBERFELD



THE MAIN STATION AT ELBERFELD



ANOTHER STATION,—ON THE SCHILLERSTRASSE

of a century hence" was not really an entire novelty. The Barmen and Elberfeld road, too, did not remain merely a road on paper; actual construction began not very long after the first agitation of the project, and early this year the line was given over to traffic with ceremonious inauguration proceedings in the presence of the Emperor and Empress of Germany.

As early as 1821 a certain Henry Robinson Palmer, who is the first recorded inventor of a single-rail system, constructed a car consisting of two panniers suspended from either side of a rail; and in 1826 what was known as the Robinson Palmer system was being exhibited at Elberfeld in order to excite interest in a scheme for a coal railway between Barmen and Elberfeld,—a scheme which, unfortunately for its originator, came to naught.

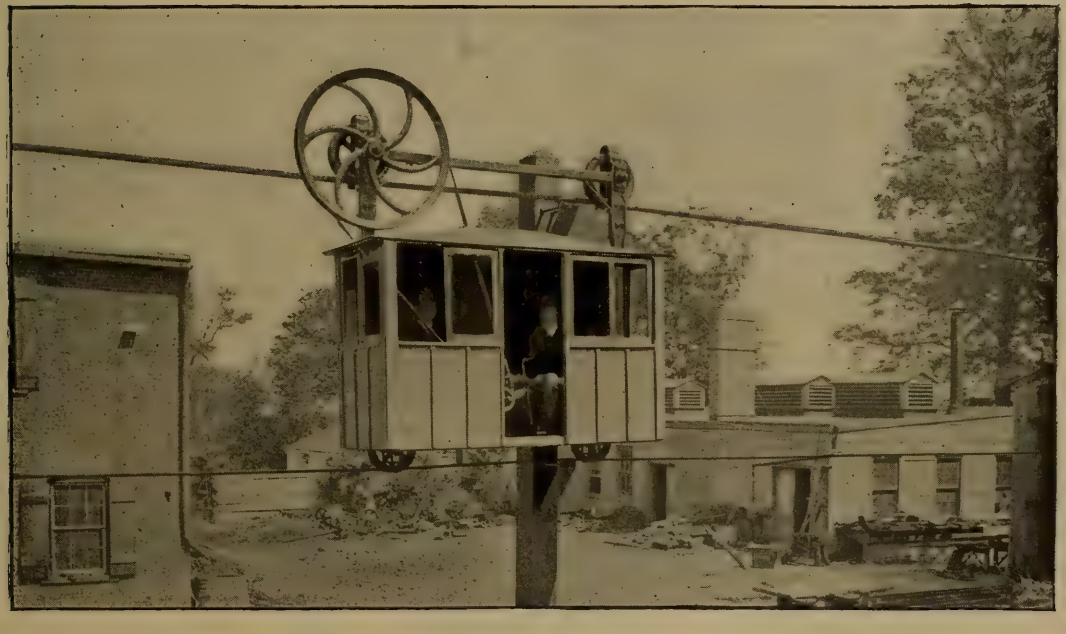
When, in 1893, the municipalities of Barmen and Elberfeld contemplated the introduction of an elevated electric railway between their respective towns, they deputed three German engineers to report upon the system which Langen had devised. After numerous experiments, and a close examination into the merits and demerits of his plans, they came to a favourable decision, and, as a result, Langen was told that he could start work almost as soon as he chose. With the line now in operation and its satisfactory performance, it is probable that many extensions will be made during the next few years.

The line runs through the narrow valley of the River Wupper, and its general features are, perhaps, best explained by the several illustrations which are here given of different portions. The preponderating impression is that of the massive *V*-shaped character of the girder design,—not beautiful, it must be admitted, but with the industrial character of the district through which it passes, it is not seriously offensive, and in many ways to be preferred to smoky, noisy steam locomotive surface transportation. To the people of the district the "elektrische Schwebebahn" is a thing to be referred to and pointed out with pride.

The illustration given on this page shows a view of the line in one of the streets of the little town of Vohwinkel through which it passes. There the flat-top *V*-girders have been abandoned in favour of an inverted *U*-shaped structure, so as to give a clearer space for street

THROUGH THE STREETS OF VOHWINKEL

DAFT'S EARLY SUSPENSION RAILWAY IN THE UNITED STATES



A ROPE SUSPENSION CAR

traffic underneath. For the geater part of its length the railway runs immediately above the River Wupper, and we get a very good idea of what it looks like from the views on page 499, which were taken near Elberfeld. A fairly sharp curve is shown in one of them; but, contrary to the general idea, there is no oscillation of the cars when running round a bend. But the engineers, when conducting experiments in connection with this point, placed vessels of water on the floors of the carriages, and though when running at high speed these became inclined very considerably from the perpendicular, not a drop of water was spilled.

There are stations at intervals of about two-fifths of a mile, making the stoppages rather too frequent for really fast

travelling. Illustrations of two of the stations are given on pages 500 and 501 with cars just entering them.

The carriages used on the line are built somewhat after American pattern, a corridor running down the centre. In length they run to nearly 40 feet, and in width to slightly over 6 feet. Fifty persons can be accommodated in each compartment, and thus each train, which ordinarily is composed of two cars, is capable of carrying about a hundred passengers. The weight of the two carriages,—passengers and electric motors included,—is about twenty-eight tons, making a carriage weight of about 618 pounds per passenger. The cost of the line amounted to only about £55,000 per mile.

As implied above, electric power is used for the system, the current being supplied from the recently built electrical works at Elberfeld. The road was built by the Continentale Gesellschaft für Elektrische Unternehmungen, of Nürnberg.

As an interesting practical forerunner of Mr. Langen's railway, mention should be made here of a somewhat similar line, though purely experimental in character, put up by Mr. Leo Daft in the eighties at Greenville, New Jersey, U. S. A. It ran over only a very short distance, and never attained the dignity of anything beyond an experiment; but as shown in the upper one of the illustrations on page 503, it had a rather promising, businesslike appearance. The lower illustration on that page represents a modification of the same idea, also installed by Mr. Daft at that time in conjunction with his other pioneer electric railway work. The large car was equipped with gearless motors, four in number, and operated for some weeks on the track shown in the picture, which was built in Mr. Daft's factory yard at Greenville in the spring of 1886. A gradient of 6 per cent. and a curve of 45 feet radius were included in the experimental track, on which considerable running was done, though partly owing to the mistake in adopting gearless construction the operation was not so prompt or vigorous as it could easily have been made by adopting single reduction gearing; but this seemed to be extremely distasteful to the promoters of the enterprise, who were making a point of claiming high speed as a special feature.

The smaller rope suspension car was also run on the experimental track shown in Mr. Daft's factory yard. This was the invention of the Chandler Brothers, of Boston. The whole affair operated perfectly for several months.

A NEW WORKING DAY IN BRITISH SHOPS

By T. A. Wheatley

THE article on the above subject in the July issue of this magazine is very interesting and of exceptional practical importance. The present writer is a member of a firm who adopted the following arrangement of working hours ten years ago:—

Monday—8 to 12 and 1 to 6	9 hours.
Tuesday to Friday (inclusive)—7 to 12 and 1 to 6	40 "
Saturday—7 to 12	5 "
Total working week	54 hours.

Breakfast is taken before beginning work. Workmen are admitted at 7 A. M., 7.30 A. M., and 1 P. M. That a working week thus arranged is of material advantage to the employer, as compared with the old plan, needs no demonstration. The main points in its favour are, however, detailed below.

No change such as that under discussion is justified if its object is to benefit the employer at the expense of the em-

ployed. If, however, no disadvantage accrues to the workman, objection cannot be taken to masters improving the system under which they conduct their business. Should experience go to prove that the division of the working day into two parts instead of three tends to improve the health and create the general well-being of workmen, it is difficult to believe that the present custom can much longer obtain in shops otherwise conducted on up-to-date lines. It may be observed here that the general practice is a survival from the time when longer hours were in vogue, and that an arrangement quite necessary then is not so now.

It is probable that a reason why British employers have not decided to follow the example of American works in this respect is the anticipation that it may be made a peg on which to hang a demand for shorter hours. It would, however, appear from the cumulative testimony of those best able to express opinions on the subject that not only must the length of the present working day be maintained, but a much larger resultant must be secured from it if the British manufacturer is to survive in the commercial battle already in an acute stage. If the change advocated in the article under review serves this purpose in any degree it is a strong reason why it should be welcomed by master and man alike in the interest of British national prosperity.

The following are among the advantages secured to the employer by the adoption of the hours given above:—

1. The works are opened at 8 A. M. on Monday. It is common knowledge that only a small percentage of workmen attend in shops opening at 6 A. M.

2. The day being divided into two parts instead of three, one entry and one exit of men are avoided. The average time wasted in waiting for and preparing to leave for breakfast and time lost between the nominal and actual time of restarting is a matter of conjecture, and is dependent on the discipline obtaining in various factories,—perhaps ten minutes per man will be accepted as a fair estimate, in which case the loss per 100 men amounts to 100 hours per week, and as some of these will be machine hands, it may be taken as equivalent to two men and one machine in every hundred remaining always idle. If the wages paid are per day it is equivalent to a loss of £200 a year in every 100 men employed, and in any case the loss of 1 per cent. in machine production.

3. It is notorious that the common practice of opening works at 6 A. M. is prolific in lost quarters. The temptation to defer starting until after breakfast is too strong when the preceding evening's amusement is unfavourable to early rising, or the morning is not inviting. If the penalty for sloth or carelessness is the loss of half a day, it is apparent that neither can be freely indulged in, and a marked improvement in attendance is the result.

It is suggested in the paper originating the consideration of this subject that an advantage to be gained by the later start is that less artificial light will be required, but this is a mistake. Taking the hour of sunrise and sunset at the mean for each month, it will be found that little or no advantage rests with either system in this respect. The spring months are not favourable to the early bird to the extent of eleven minutes in February and fourteen in March, but it has its revenge in October, the morning light exceeding the evening by twenty nine minutes; the remaining months are either quite dark or quite light between the hours of 6 and 7 A. M. and 5 and 6 P. M.

4. Bookkeeping is considerably reduced, two sets of figures answering the purpose of three, and chances of mistake are, therefore, proportionately less.

5. As supervision is most effectual during general business hours, it follows that a distinct advantage accrues if the factory is running from 5 to 6 in the evening instead of from 6 to 7 in the morning.

6 It will be found to facilitate business for shop and office hours to be, as far as possible, identical.

There are several other considerations which cannot be conveniently given in

detail in the course of a paper seeking to condense the salient points of the subject.

That the American method does not immediately lend itself to the habits of the British workman is a fact, and, until tried, is, therefore, objected to; but it may be said that workmen who for forty years have lived under the old régime have stated that they would be sorry to go back to it after becoming accustomed to the new.

If the home of the workman is sufficiently near for him to go there, breakfast, and return in half an hour, undoubtedly it is more convenient to have the morning meal at 8.30 than at 6.30; but in most cases, and especially of late years, when the home of the workman is at a distance, breakfast is taken at a coffee house, the proprietor of which is delighted to see his engineering customers at the earlier hour, allowing him space to accommodate and time to attend to other customers at the later hour. It is contended that five hours between breakfast and dinner and the evening meal are too long an interval, but it is about the average time recommended to a healthy person, and accords with the general practice of business men.

The question of vital energy and the importance of being fortified for the exhaustion of labour were dealt with in the previous article. It is an interesting point as to how far the stinted growth of the British working population is due to this cause. That a man is better fitted for work after his morning meal than before it accords with the experience of the majority of people, and if three meals a day are taken, say, at 6.30 A. M. 12 noon, and 6.30 P. M., they will be found to lend themselves better to a healthy frame of mind and body than meals taken at 8.30, 1 o'clock, 5.30, and 9 o'clock.

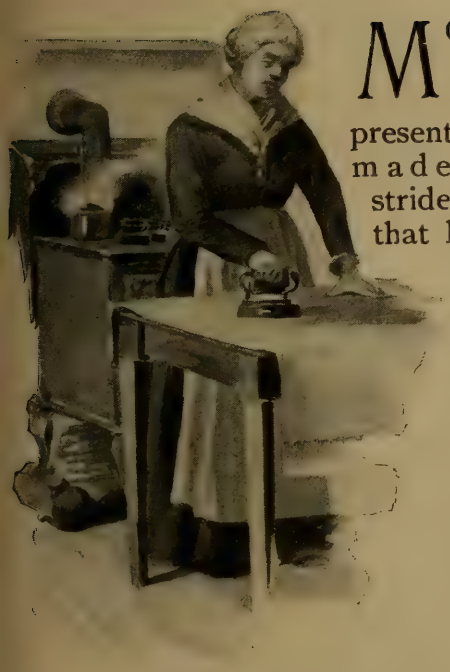
The extra hour on Saturday is greatly appreciated, enabling workingmen to reach home, have dinner, and be in time to join in whatever sport or pastime they delight in.

After careful observation during a lengthened time the writer has formed the opinion that the hours mentioned above effect a considerable saving to the employer and are distinctly favourable to the workman.

LAUNDRY MACHINERY

SOME RECENT BRITISH DESIGNS

By James L. Couper

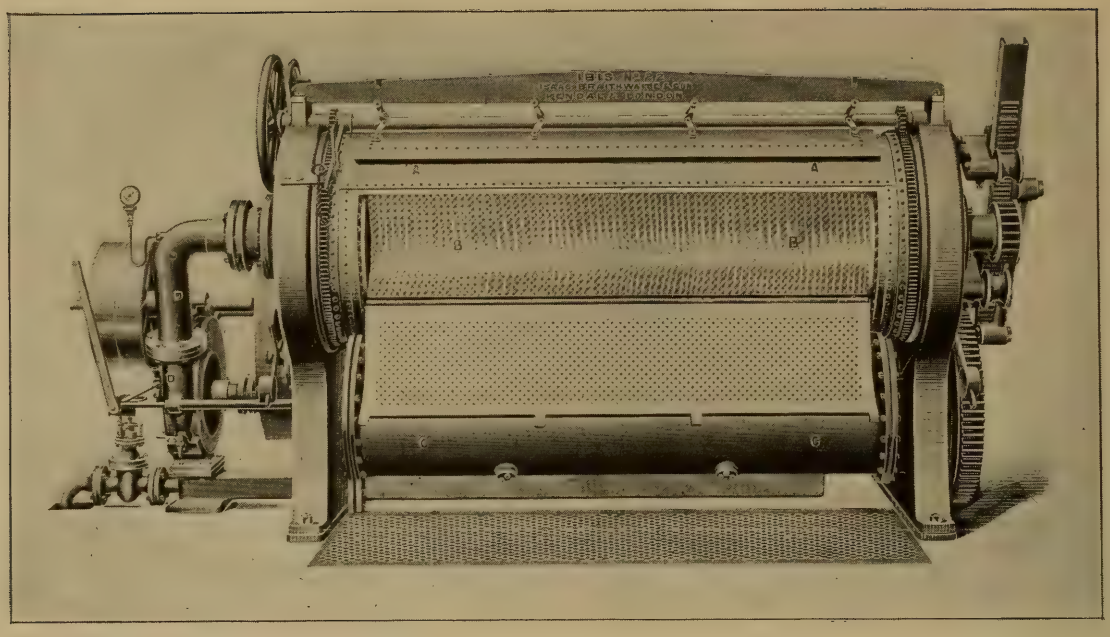


MOST of the machines used in laundries at the present day have not made the immense strides in improvement that have taken place in machinery for most other purposes, and it will be found that many laundries are still being fitted out with almost the identical machinery that was employed over twenty years ago.

In washing machines the favourite one is still the same one that was on the market many years ago, — that is, a revolving cage, into which the clothes are put, working inside a cylinder containing the washing liquids. There have been a few changes in the size and form, but the Americans, who are decidedly quick in appreciating the good points of machines, have always kept to small diameters of washing cylinders. The advantage in this is that the load can never be so heavy that the washing liquid cannot readily find its way to every article, and the articles change their position much more freely than when in great quantities. It is the motion and friction of the articles being washed on one another, together with the materials used in the water, that removes the dirt in them.

It is a long-exploded idea that forcing the water through clothes will make them clean. Forty years ago the Niagara washer was very much in evidence. This was an adaptation of the standpipe used in large boilers for boiling yarn, and it certainly created and maintained a current of the washing liquid. But although this was suitable for yarn, the result on made-up clothing was quite different, as water will always take the easiest or readiest course. Consequently, if the clothes had not been well washed on the thicker parts before being put into the boiler, there was not much advantage, at least not enough to make the apparatus keep the market. The boiling and the current of water

A BODY LINEN IRONER



WASHING MACHINE MADE BY MESSRS. ISAAC BRAITHWAITE & SON, KENDAL AND LONDON
THE SOAP SOLUTION AND THE RINSING, BLUING, OR STARCHING WATER ARE DRAWN FROM SEPARATE RESERVOIRS BY THE PUMP AT THE LEFT AND ARE DISCHARGED DIRECTLY IN SMALL STREAMS ON THE CLOTHING IN THE WASHING CYLINDER PROPER

certainly clarified the materials if the water was changed often enough, but the seams and thicker parts, such as neck and wristbands, had not the same benefit as the thinner portions through which the water more readily finds its way.

Rotary washing machines at first were always moved in one direction, but this caused so much entanglement amongst the clothes that reversing gear had to be introduced. To economise space, machines of large diameter were introduced, but these did not give the increase of work due to the space and power required, and the heavy body of clothes made the tear and wear greater in proportion; and if loaded in the same proportion as machines of smaller diameter, the percentage of badly-washed articles became very great.

The inside-cylinder arrangement of washing machines has been varied considerably, but until lately the division of these into two, three, or four compartments has not had the attention due to the benefits accruing. The first plan tried was to divide the cage into two equal semicircular parts, and was given up, probably because being in a large diameter cylinder, the centre division gave too much of a slide and dash, as beaters or tumbling ridges were not then in use. Then when the dividing part was perpendicular, the whole load was at the bottom, and the power required to drive was necessarily great.

The plan of dividing the cylinders into three triangular compartments, having ridges on each of the three sides of the triangles, is a distinct improvement in every way for machines which are constructed to wash, boil, and rinse, before taking out the charge. This plan of cylinder gives the greatest number of changes in position to each charge, along with a good deal of compression each time the clothes fall into the corners of the triangular spaces. It also gives a more perfect change of water. As the partitions are perforated, the water falling from the top division plays on the contents of the under ones, so that if there is any advantage in current of water it is well utilised. Furthermore, as there is a shaft passing through the cylinder, the machines are far more durable than when made with gudgeons, thus saving a great deal in repairs.

In the latest machine for washing, a centrifugal pump delivers the washing

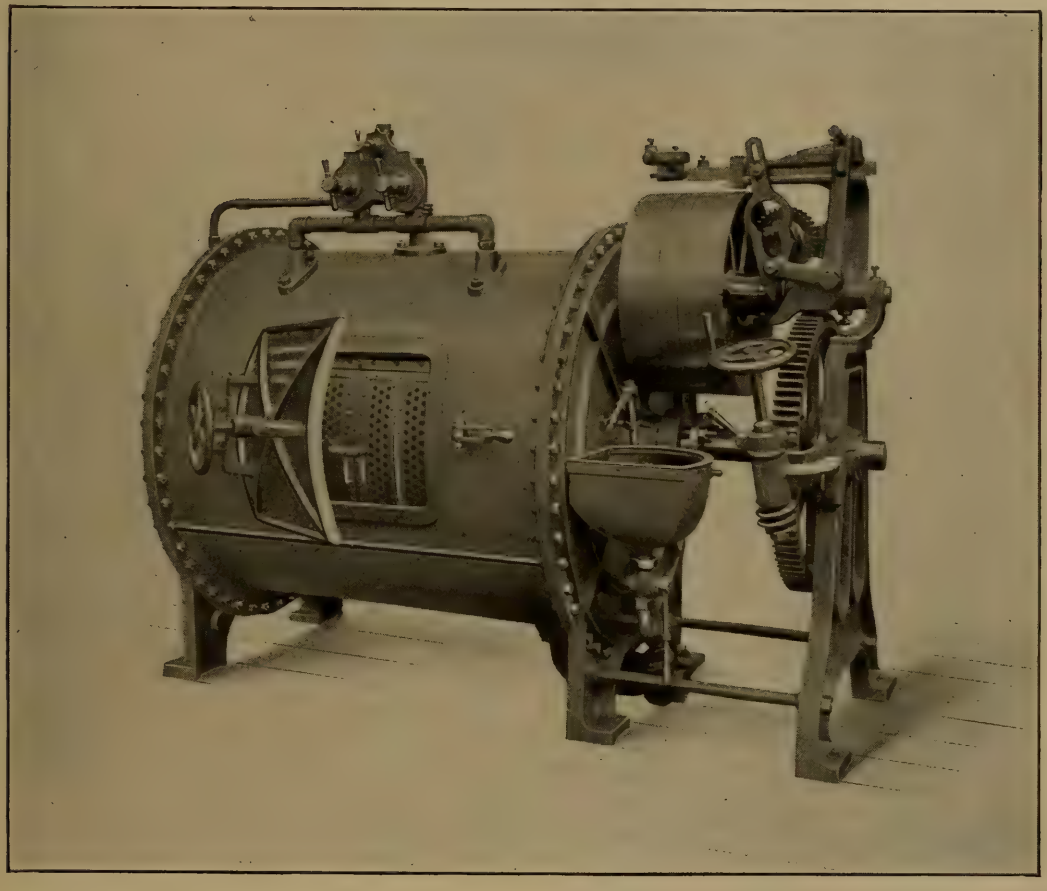
liquids with considerable force on the goods in the cylinder whilst it is being slowly rotated. The liquid is in the under compartment, and falls back into it after striking the goods. This machine is in a good many laundries on the Continent.

As to hydro-extractors, it is only of recent years that machines of the suspended, self-balancing type have come into anything like general use in laundries, although they have been made for dye works and sugar refineries for many years.

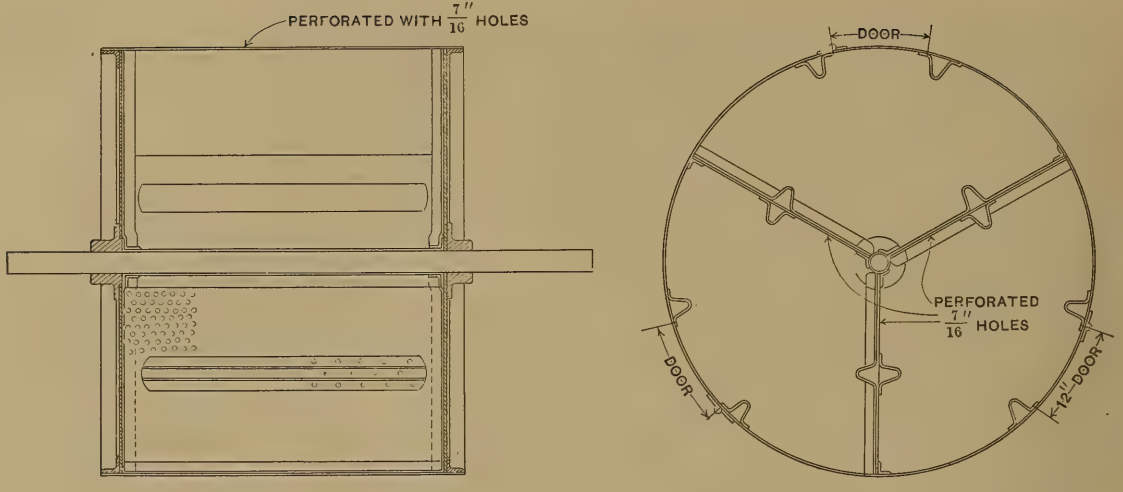
With these a much deeper basket can be obtained, and consequently a greater load in a smaller diameter machine than is possible with underdriven machines. Baskets of 30 inches to 36 inches are most convenient, because there is not the same danger of tearing clothes, through bad loading, when the clothes expand towards the periphery. A good deal of misconception exists about the number and size of the perforations necessary to effect the drainage of clothes in an extractor. Many laundrymen hold that wired baskets are absolutely necessary. This is not the case, although there is a danger of spotting goods that have been heavily blued by reason of the water passing off at too few perforations This fault has been overcome by lining the basket with wire netting, thus leaving the basket much stronger and safer than if it had innumerable perforations.

The fact that it requires no foundation, is very economical in power required to drive, and can be driven from the right or left side, or at right angles, makes this type of machine by far the most handy one that can be had.

Latterly considerable attention has been given to electric driving for hydro-extractors. Driving by means of water motors also is a neat and convenient way. With either method there is no shafting to be looked after, space is saved, the speed control is perfect, and



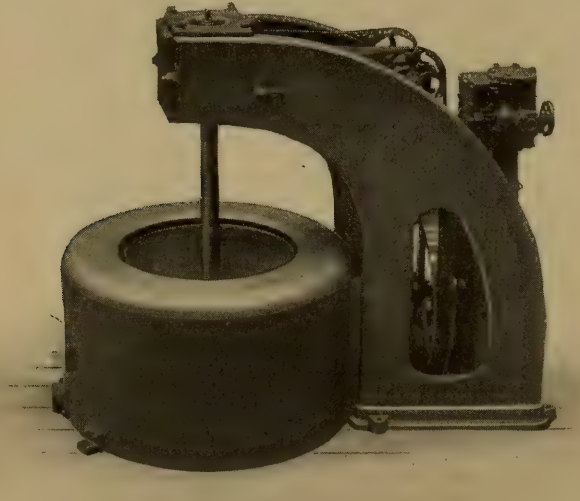
A WASHING MACHINE MADE BY MESSRS. W. SUMMERSCALES & SONS, LTD , KEIGHLEY



LONGITUDINAL AND CROSS SECTIONS OF A WASHING MACHINE CAGE

the machines can be placed in any convenient position in the wash house.

Coming to the operation of drying, either in rooms or in closets fitted with draw-out horses, the main object is to economise heat and get the full benefit of what is expended. For a very long time drying was done by steam pipes laid at, or under, the floor line, the heat passing up through the linen and taking a little of the moisture with it and also a great deal of the profit in the shape of unutilised heat. Currents of heated air have also been long in use, sometimes heated by apparatus made to utilise exhaust steam, and very frequently by live steam, or by the application of external heat. The last two methods are expensive. If the exhaust steam is used for some other purpose, then the waste gases from the boiler furnaces, on their way to the chimney, can be utilised, and there is no doubt that the best plan for getting the best results from these gases is obtained by using the same apparatus that has been employed with success and profit to heat water for many years, namely, the economiser.



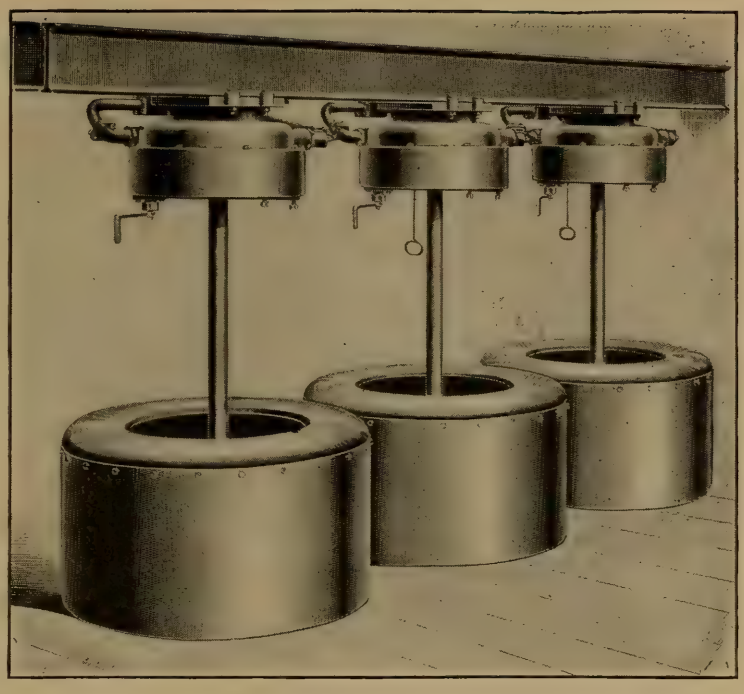
A SUSPENDED HYDRO-EXTRACTOR WITH VERTICAL ENGINE, MADE BY MESSRS. WATSON, LAIDLAW & CO., GLASGOW

Until late years economisers were never thought of for laundries, but now their use every day is becoming a greater necessity for first-class laundries. One-third of the economiser may be used to heat feed-water, and the other two-thirds to heat air. When the writer commenced to use the economiser for air, he had to make the altered fittings for that purpose, but Messrs. E. Green & Sons, Ltd., of Manchester, now make a specialty of fitting these economisers for air as well as for water. This is true also of the American makers, the Green Fuel Economizer Co., of Matteawan, N. Y.

The old method of putting in cold air at the bottom of a closet and allowing it to escape at the top, will not suit with hot air drying. The saturated air must be drawn off at the bottom, and if, the heated air is blown in with a strong enough current there

will not be any need for mechanical extraction.

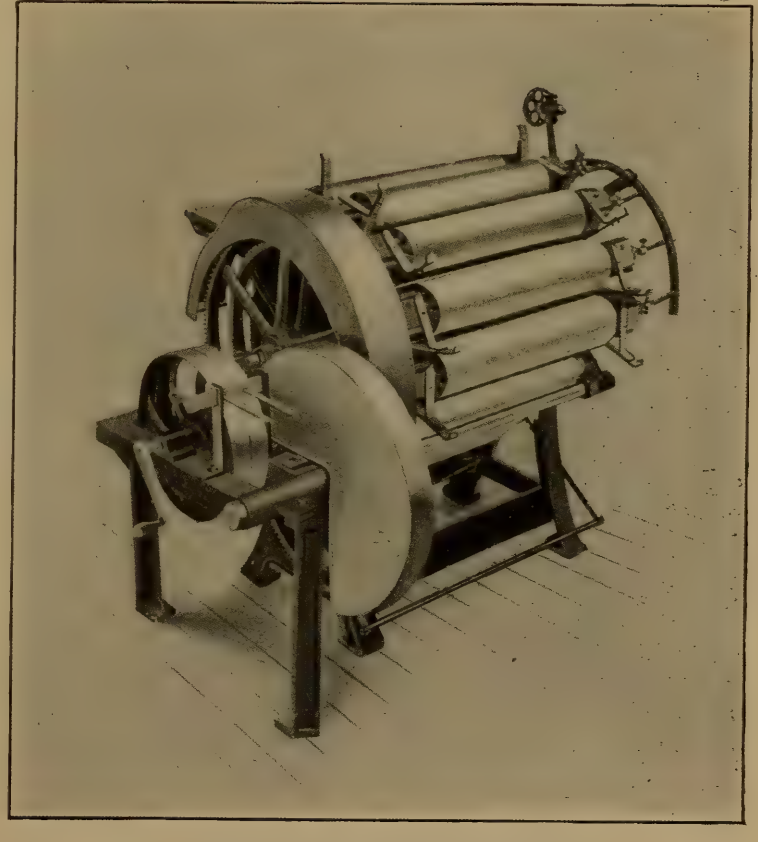
In small laundries, or where there is no convenience to fit up an economiser, a very good and satisfactory plan, when the drying closet is on a higher level than the boiler, is to make the heating pipes a part of the boiler by taking the steam away from the top of the boiler and taking the return pipe in under the water line. Many have tried this method and failed through not giving it enough consideration. To ensure proper working, no matter what the area of heating pipes may be, the steam pipe or inlet must be twice the area of the return pipe to the boiler. Then, when starting to heat the closet, the steam should be turned on to the heating pipes, and the condensed water allowed to escape at a tap placed just before the return pipe enters the boiler. Immediately the water is all off and steam comes, shut the by-pass and open the return tap or valve.



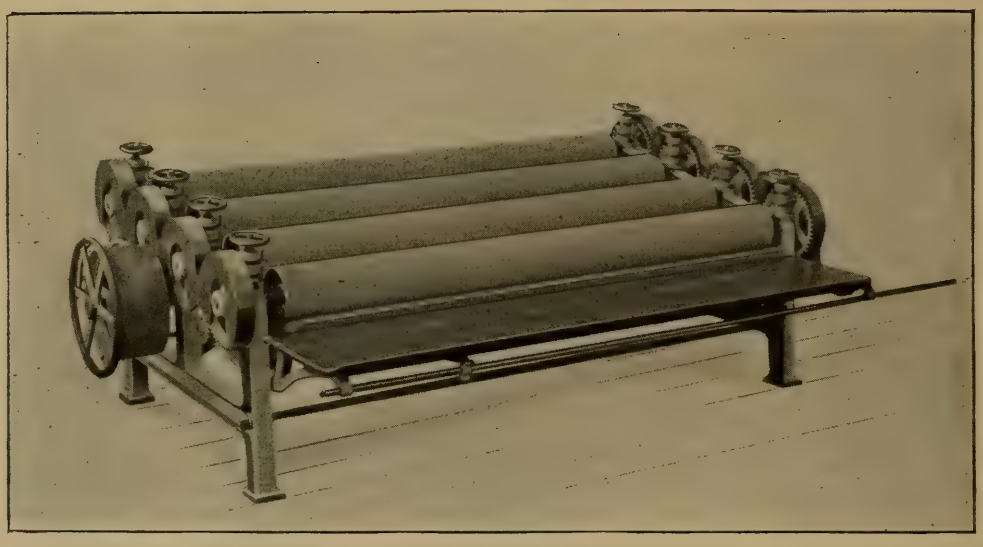
SUSPENDED HYDRO-EXTRACTORS DRIVEN BY WATER MOTORS, MADE BY MESSRS. WATSON, LAIDLAW & CO., GLASGOW

Since ironing machinery came so much into use the drying closet has not been required to the same extent as in the old days of the mangles and stove irons. The origin of ironing machines is, no doubt, found in the calender for finishing new goods; but as these goods were dampened only enough to give the finish required, the calender had to be altered to suit the purpose of an ironing machine, which was required to dry as well as finish the linen, and a considerably greater contact to the linen and the heated surface had to be provided for.

The Decoudin or shell machine was a great advance on the steam mangle or calender, but at first the roller was not heated. The next development was the introduction of steam into the



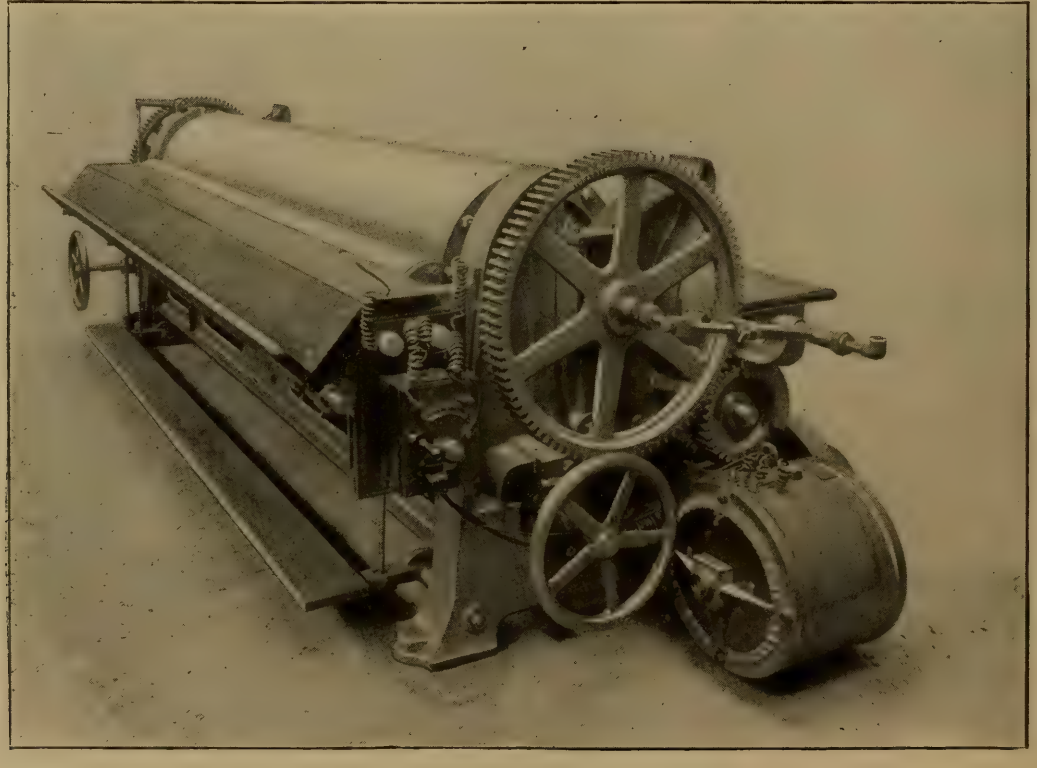
A FIVE-ROLLER IRONING MACHINE



A FOUR-ROLLER IRONING, DRYING AND FINISHING MACHINE, MADE BY MESSRS. D. & J. TULLIS, LTD., KILBOWIE IRON WORKS, NEAR GLASGOW

roller, which increased the drying power greatly. This style of machine held the market for many years, until the multiple-roller machine came into use. The principle of this machine, which was first perfected in America, is to have a long heated bed with two, four, six or eight hollows in it, where the padded rolls press on the goods being ironed. The goods are at these points smoothed while under pressure, the moisture being evaporated whilst the materials pass over the space intervening to the next roll. This evaporating space is of immense benefit to the speed in drying.

In the single-roll machine almost one-half the roll is absorbing moisture while the other half is evaporating it, the consequence being that if driven too quickly



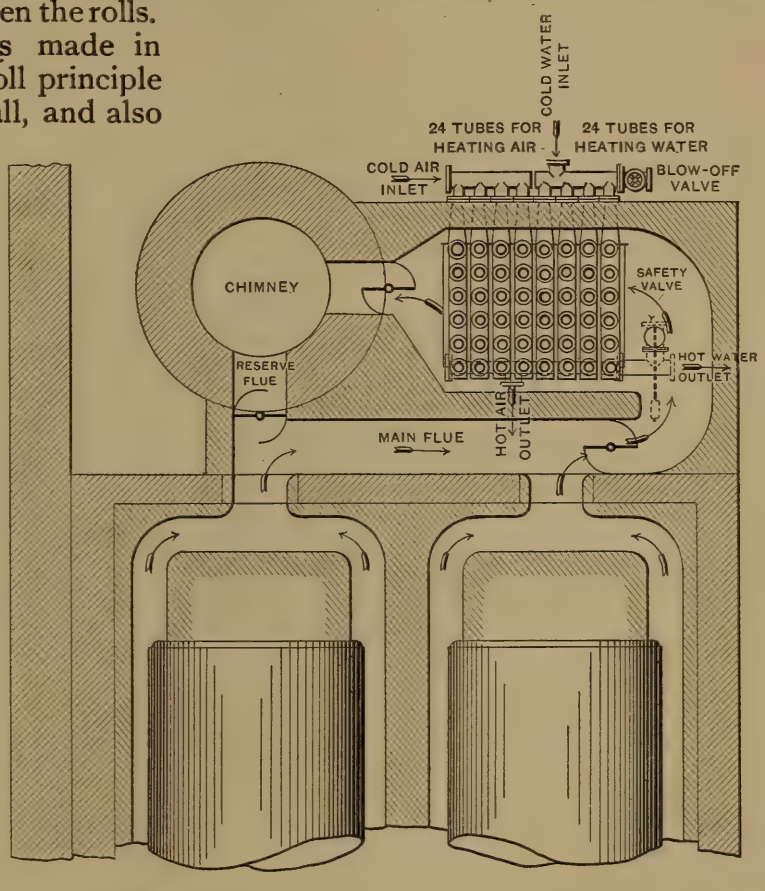
AN ELECTRICALLY DRIVEN IRONING MACHINE, ENTIRELY SELF-CONTAINED, MADE BY MESSRS. W. SUMMERSCALES & SONS, LTD., KEIGHLEY, ENGLAND

the padding becomes saturated, and the machine has frequently to be allowed time to dry. With the multiple-roller machine, on the other hand, the contact is less than one-fourth the circumference of the roll, allowing three-fourths for evaporating service, and the speed is further accelerated by evaporation going on from the goods whilst passing over the spaces between the rolls. The fault of most machines made in Great Britain on the four-roll principle is that the rolls are too small, and also that the linen, after passing through the machine, falls in folds of heated cloth, one over the other, and the steam thus does not get thoroughly out

This fault is overcome in American machines by passing the goods under, and in contact with, the bed of the machine (which is polished) on a travelling cloth, thereby doubling the amount of the heated surface, and after leaving contact with the bed of the machine it is conveyed back to the delivery end between two cloths. These cloths are always warm and very dry, thus absorbing the last particle of steam or moisture that is in the goods.

Body linen ironing machines may be classed into two kinds, — gas-heated and steam-heated. With gas there is always the danger of overheating and scorching. With steam the difficulty is to get sufficient heated surface applied to dry and iron goods right from the hydro in one passage. Most body linen machines are made with one ironing roller and one padded roller, but as this gives very small contact, the operation has to be repeated several times. There are steam machines with inverted concave ironing surface having 13 inches of ironing and drying contact capable of ironing starched muslin aprons in one passage, a very great consideration in the time and expense of handling.

Coming to the collar and shirt dressing machines brings in the question of boiled *vs.* raw starch. Boiled starch, although not universally adopted in America, is in much greater favour and practice there than it is in Great Britain, its greatest drawback no doubt being the greater humidity of the British atmosphere, as boiled starch does not retain its stiffness as well in a moist atmosphere as cold water starched goods. Machines for raw starch require greater heat and much longer application than when using boiled starch, but as raw starch is in more extensive use in Great Britain, machines there must be made accordingly. Too many laundry men and machine builders aim at making one machine dry and polish. This will never be possible profitably, because to get the full benefit of heat, time must be allowed for evaporation before applying



AN ECONOMISER FOR FEED WATER AND AIR HEATING, MADE BY MESSRS. E. GREEN & SON, LTD., MANCHESTER, ENGLAND, AND THE GREEN FUEL ECONOMIZER CO., MATTEAWAN, N. Y., U. S. A.

heat again. The best machine for this is the five heated roll ironer. To get its best results the collars must be brought to an almost dry condition and passed through the machine so as to come out perfectly dry, as subsequent evaporation destroys or lifts the gloss.

Gas irons have been in use now many years, but it is only of late that any attempt has been made to improve the heating power by supplying air from pressure blowers instead of ordinary fans. It requires five and a half cubic feet of air to each cubic foot of gas to insure the best results, and if this is supplied at a pressure of one pound per square inch the results will be gratifying.

Current Topics

It is not so many years ago that the firing of high-explosive shells from ordinary guns with powder charges was among the things yet unattained. The high-explosives of that time had not the requisite insensibility to heat and shock to make the proceeding safe, and as a consequence there cropped out compressed air guns and others of involved construction, using powder charges, but having curiously disposed large gas chambers, all calculated to start the high-explosive shell gently on its journey. The compressed air guns are today interesting relics. Their only service was during the bombardment of the Santiago batteries in the Spanish-American war of 1898, when they were brought into action on board the United States dynamite cruiser *Vesuvius*, and then they did little, if any, execution. One gun of this kind is still mounted at the entrance to New York Harbour, at Sandy Hook, ornamental, however, rather than useful. Of the special powder guns for throwing high-explosives very little, too, is heard, and now that the new high-explosive "maximite," named after its inventor, Mr. Hudson Maxim, has come on the scene, there seems little reason for their existence. Mr. Maxim's explosive, as recent United States Government tests appear to have shown, possesses in a marked degree the two already mentioned essential properties which make a high-explosive suitable for charging projectiles to be fired from ordinary guns, namely, insensibility to heat and to shock. To test its susceptibility to chemical change, it was maintained at a temperature of 165° F. continuously for fifteen minutes. When ignited it burns fiercely without exploding. The resistance to

shock was determined by a drop-test, after which it was loaded into a 5-inch projectile, and fired through a nickel-steel armour plate, without producing explosion. The shell was then armed with a fuse and exploded, being torn into about 800 fragments. A 12-inch shell which was similarly charged burst into about 7000 fragments. Maximite fuses at a point below the boiling point of water, an advantage which safeguards it against ignition by the heat of friction set up in the shell due to the rapid rotation of the latter. The instant heat is produced, the surface of the material melts and forms a frictionless bearing between the bulk of the explosive and the shell, greatly diminishing the tendency to heat further. It also possesses the quality of expanding in passing from a fluid to a solid state; this causes the material, after being run into the projectile, to adhere firmly to the walls and fill the entire cavity, and precludes the possibility of entrapped air and its attendant disadvantages. The composition of maximite is kept secret.

A MOVEMENT of manufacturing plants away from "strike areas" is one of the noteworthy features of the American steel trades labour troubles now in progress, and represents a strike factor which has probably never before come so prominently into the reckoning. Attention was more particularly drawn to it by the dismantling of the famous sheet steel mill at McKeesport, in Pennsylvania, which was directly induced by the recent lawless utterances of the mayor of that town and the trades people's sympathy for the strikers' cause, and since then preparations have been made in several other strike-ridden communities to abandon old established works for more congenial localities. Examples of such works removal are not new; they can be found scattered along at intervals during the past dozen years or more. But they came singly, and, therefore, did not teach nearly so striking a lesson as the now threatened wholesale abandonment of towns which, in some instances, have thus deprived themselves of their sole means of support. In Great Britain trades union despotism has driven some industries completely out of the country; in the United States, as now foreshadowed, it will bring about a new geographical distribution simply within the country's own borders. But the teachings of the movement are essentially the same in both cases. Where the rights of corporate bodies are no longer respected and where violence controls a community, the risks to industrial plants are too great to warrant a continuance of business.

PROBABLY the last thing for labour unions to admit would be that their influence is entirely reactionary. Yet such, says the New York *Sun*, is the case, as can be readily shown. Sir Henry Sumner Maine pointed out in his "Ancient Law" that the most important step in the evolution of society was taken when a change was made from a condition of "status" to one of "contract." In early times a man's position in the community, his trade or calling, were fixed, and there was no way in which he could escape from the limitations which bound him. That was a condition of "status." Then came the more highly developed stage of "contract." The individual made his own bargain. He stood on his own feet. He was the unit. His success depended on his own skill and ability. The modern unions have tried to bring back the archaic condition under which the individual did not count. They have striven to put workmen into artificial families in which all share alike, the able witn the incompetent, the lazy with the industrious. Ability is handicapped so as to give the other thing a chance.

WITH the excellent example set on the Charleroi Canal, in Belgium, of what may be accomplished by electric haulage on inland waterways, it seems reasonable enough to look for exten-

sions of the system in many other places. One of the first of these promises to be along the River Lea, in the northern suburbs of London,—a busy little stream with a considerable barge traffic, which it is now proposed to develop, and the manufacturing industries along its banks as well, by introducing a system of electric towing. So far as can be learned at this early date, the scheme is to be modeled somewhat closely after that used in Belgium. A species of electric automobile is to be used, traveling along the river bank, taking current from an overhead trolley wire, and hauling the barges by means of a tow line. It will be the first electric power application of its kind in Great Britain.

Of the erection of the much-talked-of Gokteik viaduct in India, Mr. J. C. Turk, the engineer in charge for the Pennsylvania Steel Company, gives an interesting account in the *World's Work*. "Any great engineering project carried on 15,000 miles from home," says Mr. Turk, "is bound to be full of difficulties, since all kinds of unforeseen accidents are likely to occur. At Gokteik we had no sooner emerged from the rains than we were confronted with the problem of handling, sorting, and storing our material at the starting point of the viaduct in a cramped, inconvenient spot on the steep slope of a hill. In America a few carloads of material can be shipped as they are needed, but out there a second steamer load,—comprising a full third of our material,—was upon us before the first load had been properly stored, and just as we were establishing our plant and beginning actual work in the field. The confusion was indescribable. The storage yard at the bridge head became a scene of the maddest activity. As the material came in from Mandalay, our big steam derricks whipped it out of the little, meter-gauge freight cars, and swung it over to the smaller derricks for final disposition; and coolies swarmed about with smaller pieces like ants in a stirred-up ant-hill. The work went on with such speed that the native engine drivers and train hands could not shift empties in time to keep clear of the rush. So when too many of them accumulated, we picked them up with the 15-ton steam derrick, and set them down on the bank,—where the drivers of the switching locomotives would discover them, 50 feet below the level of the track, piled up like empty dry goods boxes. * * *"

"The American workmen proved so efficient, as compared with the natives, that, roughly speaking, I should consider one American equal to at least four natives. Divided into castes and subdivided into trades, the natives were able to do but one kind of work; though in an American rivet gang there are but three men, all capable of doing any part of the work, the Indian natives are obliged to have in their gang a hammer man, a snap-man,—to hold the form on the rivets,—a man to hold under the rivets the big iron dolly-bar, a man to heat the rivets, and one to pump the bellows. The bellows man cannot heat rivets; the rivet heater cannot swing a hammer; the hammer man cannot hold the dolly-bar, and when the gang are obliged to move, they have to wait for the *khallassies*, or riggers, to rig their stagings. When the painting began on the viaduct, I found the painters, too, quite useless without the *khallassies*. Good workers at their trades they were, however, all of them, the riveters from Oudh and the Punjaub, used to bridge work, and the *khallassies*, sailors mostly from coasting vessels or P. & O. steamers. Usually, on Indian bridge work, the British engineers put a thousand or two thousand of these natives under one or two Europeans, for they are as docile as sheep, and have the same respect for their European overseers that sheep have for a collie; but we introduced the innovation of having white men work. On the traveller, on the material as it went up, on the topmost points of the rising towers to connect the new pieces as the crane swung up, the Americans,—and a few British and German sailors

TRAM RAILS DESTROYED BY FIRE

I had picked up, with one North Carolina negro who spoke Hindustani,—worked hard, to the measureless surprise and admiration of the coolies, so that as soon as the construction of the viaduct got well under way operations went on with tremendous rapidity, some of the 200-foot towers, much like New York skyscrapers, going up in three or four days."

THROUGH the courtesy of Mr. James F. Lardner, secretary of the Tri-City Railway Company, of Davenport, Ia., U. S. A., it has been made possible to reproduce on this page a photograph of a portion of the tramway line in that city as it appeared after a recent extensive fire which destroyed several large lumber yards and about fifty residences. The fire was so hot that it melted the trolley wire on the adjoining street and distorted the rails so badly that a length of line of about 2300 feet had to be entirely rebuilt. The rails, in warping, raised at the ends, and pulled up ties and brick paving in some places to a height of four feet, the illustration showing the effects very clearly and perhaps telling the story of destruction best.

A CURIOUS difficulty with the electric transmission system which supplies power from Apple River Falls for lighting the town of St. Paul, Minn., U. S. A., was recently recorded in the *Electrical World and Engineer*. The electric line is operated at 25,000 volts, and, on its way, crosses the St. Croix River on the Wisconsin Central Railroad bridge. The six wires are supported on 8-inch × 8-inch oak beams, extending out 16 feet from the south side of the structure, at the level of the track, each wire being 18 inches from its neighbour, and over 12 inches above the supporting arm below. In June and July of each year that section is visited by large numbers of a pale-green diptherous insect familiarly known as the "shad-fly." A large portion of the power transmitted is utilised as direct-current, through the medium of

six-phase rotary converters, and when one evening about eight o'clock the converters went "out of step," thereby paralysing the whole system, the attention of the operators at the generating station was at once directed to the St. Croix bridge, about five miles away, by a series of brilliant electric discharges. The line was cut out, and an emergency crew despatched to repair the supposed breakdown. They were much puzzled upon their arrival to find everything in perfect order, no evidence of any short circuit being visible on either wires, insulators or cross-arms. After some delay the current was again turned on, and the cause of the trouble then became apparent, for the flies soon gathered in such numbers on some of the arms that they formed a solid bridge from wire to wire, and the flash of each discharge, while it destroyed thousands, only added fuel to the flames by attracting additional thousands to the spot. The shutdown lasted about an hour, and it was found necessary to station an attendant upon the bridge, who was provided with a wooden hoe attached to a long pole, with which, from time to time, he dislodged the insects from the cross-arms, as soon as they collected in dangerous numbers.

THE average increase to the length of railways throughout the world, according to *Engineering*, is about 11,000 miles per annum, equal to nearly 2½ per cent. of the total lines existing, which at the beginning of this century extended to nearly 480,000 miles. Of the increase during recent years, 4100 miles per annum are added to the European system, 3500 miles per annum to the American system, while the addition in Asia is at the rate of 2250 miles, in Africa 1100 miles, and in Australia 160 miles per annum. In Asia particularly, and in Africa to a less extent, there has been progressive movement; but the financial crisis in Australia has affected the development of the railway system considerably during the past decade. Of the 44,570 miles added to the world's railways during the past four years, 9000 miles have been constructed in Asia, Siberia accounting for 3424, while British India added 3020, Japan 1395, and China 180 miles. Although this last-mentioned is a small addition, relatively speaking, it is satisfactory to know that within the four years the increase is from 124 to 401 miles.

THE increase in Europe is by no means great, although the total is 16,342 miles; this is equal to 10½ per cent. of the existing system, or about 2½ per cent. per annum. As in Asia, Russia accounts for about a third of the additional European mileage,—for 5145 miles; Germany has laid 2547 miles, Austria-Hungary 3350 miles, while the English quotum is only 503 miles. But it must be remembered that the proportion of railway mileage to the unit of area is greater in England than in any other country, excepting only Belgium; and in the case of Belgium the addition to mileage is only about 300 miles. Another element affecting the question is the capital involved. The cost per mile in England is double that of any other European country. The increase in the American mileage, including both continents, is 14,100 miles, of which rather more than half has been laid in the United States; but the increase there is only about 1 per cent. per annum. The mileage per unit of area is now considerably in excess of that of the whole of Europe, although it is only one-third the length per 100 square miles in Great Britain. In Africa there has been a very satisfactory development during recent years, the total mileage added in four years being 4330 miles. In other words, the addition has been at the rate of over 12 per cent. per annum. It is an indication of the beneficent nature of British rule in Egypt that the additions there have been 65 per cent., or 826 miles; while in British South Africa the addition is 494 miles; in the Transvaal, 586 miles; in the Orange Free Colony, 596 miles; and in Algeria and Tunis, 590 miles.

As already stated, the extension of transport facilities in Australia has not been great. The four years' increase is 640 miles, equal to barely 6 per cent. of the mileage existing at the beginning of 1896.

SUSPENSION railways seem to be the fashion just now in Germany, where what is known as the Langen system is being exploited to a noteworthy extent. Not only is there the line between the towns of Barmen and Elberfeld, of which illustrations and particulars are given elsewhere in this issue, but another one has just been opened for traffic connecting the village of Loschwitz, on the banks of the River Elbe, with the heights of Rochwitz. The length of the line is only a trifle over 800 feet, with a 32 per cent. grade, and thirty-three steel piers carry the rails from which the cars are hung. There are two of these, each holding about fifty passengers, and connected by a cable, so that one of the cars is making a down trip while the other is on its upward journey, the cable being driven by a steam-engine at the upper terminus

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JOHN HEMAN CONVERSE

President of the Baldwin Locomotive Works, Philadelphia

A BIOGRAPHICAL SKETCH

NEW ENGLAND has always claimed more credit for raising school houses and men than wheat crops and other staples. Her sons have overrun the small confines which mark her boundaries, and have gone forth to every section of the country. By their native shrewdness and energy they have gained a foothold wherever they have located, and many who have attained prominence and success trace their progenitors back to the "bleak, hillside farms" that abound in the New England States.

True to the traditions of his fellow people, Mr. Converse early left the parental roof to seek and obtain the success which has come to him solely by his own exertions. He was born at Burlington, Vt., in 1840, and graduated from the University of Vermont in 1861. Almost immediately thereafter he entered journalism, and was for three years connected with the editorial department of the then *Burlington Daily and Weekly Times*. Removing to Chicago in 1864, he entered the service of the Chicago & Northwestern Railway Company, in which he continued until 1866, when he removed to Altoona, Pa., to accept a position with the Pennsylvania Railroad, under Edward H. Williams, then general superintendent of that road. Dr. Williams having become, in 1870, one of the proprietors of the Baldwin Locomotive Works, secured for Mr. Converse a desirable position in that establishment. Three years later Mr. Converse was admitted into the firm, and has been connected with it ever since.

The particular department entrusted to Mr. Converse is the general business and financial management as apart from the mechanical. How well he masters these duties is evidenced by the wonderful growth of this manufacturing plant. When Matthias W. Baldwin died, in 1866, the output of the works established by him had reached a production of 118 locomotives per annum. To-day their capacity has grown to the enormous figure of over 1000 locomotives per annum. But this comparison fails to convey entirely their wonderful development, for the locomotive of to-day compares to its prototype of a generation ago as the packet steamer to

the modern ocean greyhound. The market for the works is almost the entire civilised world, and Baldwin locomotives have gone in numbers to Mexico, South America, England, France, Russia, Sweden, Norway, Australia, Japan, China, and South Africa. The Baldwin Works may be fittingly characterised as one of the few colossal manufacturing establishments of the world.

But the business activities of Mr. Converse's life do not end with this great manufacturing plant; they include also directorship in a large number of prominent financial institutions of Philadelphia, all of which receive his active attention. It would seem that such heavy business responsibilities are more than one could well carry, but Mr. Converse brings to them a well-trained mind and a wonderful aptitude in the conduct of financial matters.

In addition to all this, however, Mr. Converse still finds time to devote to some exacting public trusts. Since 1889 he has been a member of the Board of Directors of City Trusts, serving at the head of the committee having in charge all of the Girard estate without the city of Philadelphia. He has recently been transferred to the post of chairman of the household committee. He is also a trustee of the Presbyterian Hospital at Philadelphia, the Pennsylvania Academy of Fine Arts, and the University Extension Association. During the war with Spain he served as president of the National Relief Commission, which was organised in Philadelphia in aid of American soldiers and sailors. In many other ways he is connected with public enterprises. His many contributions to public objects have been most liberal. One of the principal buildings of the Presbyterian Hospital he erected entirely at his own expense. His benefactions to churches, charities, and various educational and civic institutions are constant, generous, and indicate an active sympathy with all the progressive humanitarian and religious movements of the day.

In his private life Mr. Converse has gathered around him in a quiet and modest way the luxuries which are congenial to a man of culture. In his home art, music, literature, and genial society abound, presided over by an amiable and accomplished wife who is in full sympathy with Mr. Converse's tastes and aims.

To the University of Vermont Mr. Converse is a devoted son and most liberal benefactor. Being a trustee of the university, and intimately acquainted with its needs, he has known how to make his benefactions as wise as they have been liberal. Besides endowing a scholarship and making frequent contributions to meet special needs, he has founded the "Converse Prize" for proficiency in public debate. In co-operation with his friend and partner, Dr. Williams, who shares Mr. Converse's liberal spirit and his interest in the university, he has erected for the university a number of buildings which for architectural beauty and completeness rank with the most attractive of modern houses. The structures thus erected include a number of dwellings for the use of professors, a students' dormitory building, and a building which contains the laboratories and lecture rooms for the chemical and physical departments. In 1897 the University of Vermont conferred upon him the honorary degree of LL.D.

Mr. Converse's career throughout exemplifies to a marked degree the value of trained intellect in extensive business affairs and fidelity in the administration of great trusts.

Manufacturing News

Laying East River Bridge Cables

EARLY last month the John A. Roebling's Sons Company, of Trenton, N. J., took the first important step in the making and laying of the cables for the new East River Bridge at New York. The contract was awarded to the company several months ago, and the preparation of plans and other preliminary work, as well as the main part of the contract, which is to follow, is under the supervision of Mr. Charles G. Roebling, the president of the company, who is assisted by Mr. William Hildenbrand. The work recently done was the placing in position of the 2¼-inch diameter ropes which support the temporary footbridge on which the workmen will stand during the main work of cable-laying. Several methods of getting the first line across have been employed in the past. Kites, swimmers, and other agents have been tried, but the method employed on this occasion has, it is believed, never been tried before, and seems to be a distinct advance over all previous ones. The method adopted was to carry the drum containing the cable across the river on a float, one end having been previously secured, and pay out the cable, allowing it to rest on the river bed until at the proper time it could be raised from the water and to the desired height by means of stationary engine and drum. The first cable was successfully raised on April 11, the time required being only seven minutes, navigation being, of course, suspended during that period.

The Electrical Industries of Spain

THE Spanish Government has just published an exhaustive report on the electrical industries of the country, which contains some interesting information about the present state of electrical matters in Spain. There are at present 443 electric power stations in Spain, of which 12 are in the city of Madrid. Two of the latter supply power for street railways, nine furnish power for lighting puposes, while the twelfth plant, which is still under construction, and which will be the largest of all, will supply power for both purposes. Electric light is now to be found all over the city of Madrid, and its application is steadily increasing. Three companies, the Compania General Madrilena de Electricidad, the Compania Inglese de Luz Electrica, and the Sociedad de Electricidad de Chambin, chiefly supply the electric light for the Spanish capital. The first two companies are in the hands of

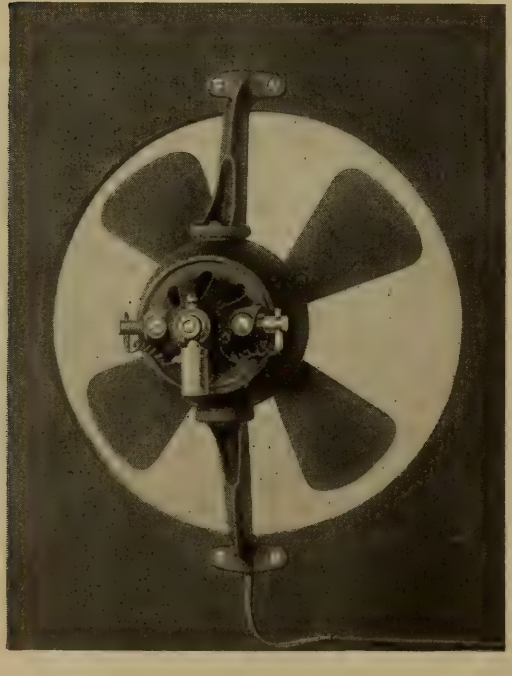
French, German, and English capitalists. The Madrilena Company has a capital of 10,000,000 pesetas (about $2,000,000), and in 1899 the dividend paid amounted to 23½ per cent. The third company, which is capitalised at 4,981,000 pesetas, is entirely Spanish.

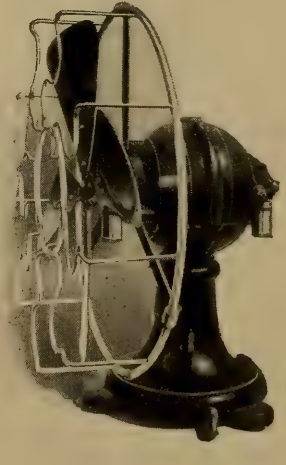
There are now in Madrid a Tudor accumulator factory, two factories for the manufacture of electrical apparatus and appliances, such as insulating material, fixtures, and instruments, etc., and a branch factory of a Paris company, which has a monthly output of 60,000 incandescent lamps. This company imports glass, wire, and other material from France, and is now enlarging its shops. A few months ago a company was also formed, with headquarters in Madrid, for the purpose of manufacturing electro-mechanical articles and all kinds of electrical appliances. This company is capitalised at 500,000 pesetas. The report goes on to say that electricity is making steady progress throughout Spain, and that a large number of electric railways are now either under way of construction or contemplated.

All the large German electrical works, such as Siemens & Halske, of Berlin; the Allgemeine Company, of Berlin, and Schuckert & Co., of Nuremberg, have their branches and depots in Madrid. Most of the electrical machinery used so far in Spain has been imported from Germany, and, to some extent, from Switzerland. Copper wire and cables are chiefly supplied by Felten & Guilleaume, of Mülheim-on-the-Rhine. The latter article is also imported, to some extent, from France, Great Britain, and Italy. Two-thirds of all electrical appliances imported into Spain are of German origin, and one-third of French, British, or Swiss origin. A large demand exists throughout the country for incandescent lamps, which are chiefly imported from Germany, France, Great Britain, the Netherlands, Sweden, Austria-Hungary, and Italy. There is, however, little doubt that the large increase in the duty rate will largely reduce the imports. Formerly the duty was five centimos; it has now been raised to twenty-five centimos.

Electric Fans

THE introduction, in recent years, of electric fans into residences, offices, shops, and public places, has provided not only the means of economical ventilation, but has afforded agreeable protection against flies. One of the first electric fans put on the market was the invention of Mr. Robert Lundell, whose name it still bears, and Lundell fans have steadily held their early reputation for high efficiency and great durability, due to excellent design and construction. Every fan is thoroughly tested before leaving the shop.





LUNDELL FANS, MADE BY THE SPRAGUE ELECTRIC CO., NEW YORK

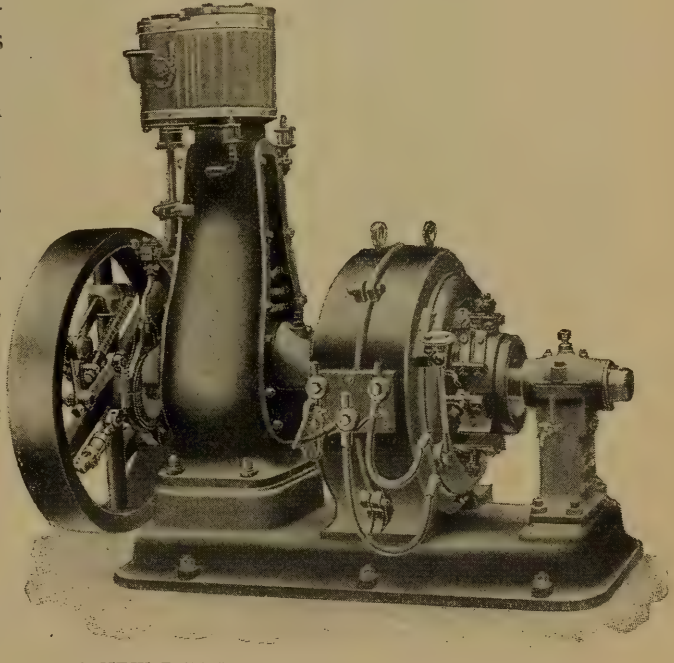
The fans have a strong torque, and give a maximum of breeze for the amount of power consumed. They

Manufacturing News

A New Direct-Connected Set

IN view of the rapid extension in the use of direct-connected electrical generating sets and the developments which these have undergone, it is interesting to notice the varying forms which they take to adapt themselves to different service requirements. In those places where floor space is limited, or of great value, as often it is in the power plants of large cities, the compactness of direct-connected dynamos with vertical engines is a feature of great utility.

The engraving presented herewith shows the standard Buffalo Forge Company's single vertical engine direct-connected to a Lundell dynamo manufactured by the Sprague Electric Company, of New York City. Some of the refinements of direct-connected machines illustrated in this set may be of interest. The engine of the Buffalo Forge Company, Buffalo, N. Y., which is here illustrated and described may be connected, of course, to any standard type of generator, and for such purpose the cast-iron sub-base is varied to conform with the requirements of individual cases. In addition to providing a bed for the engine and dynamo, it likewise carries the out-board bearing, which, in this case, is of the standard Buffalo adjustable type, ring-oiling and self-aligning. The cast-iron frame is formed with a graceful contour, provides for the guides within, and carries above the cylinder and valve chest. The connecting-rod is of forged steel, provided at each end with wedge-adjusting devices. The crankshaft, which is large in diameter, is carried in long bearings,



A NEW DIRECT-CONNECTED SET BUILT BY THE BUFFALO FORGE CO., BUFFALO, N. Y.

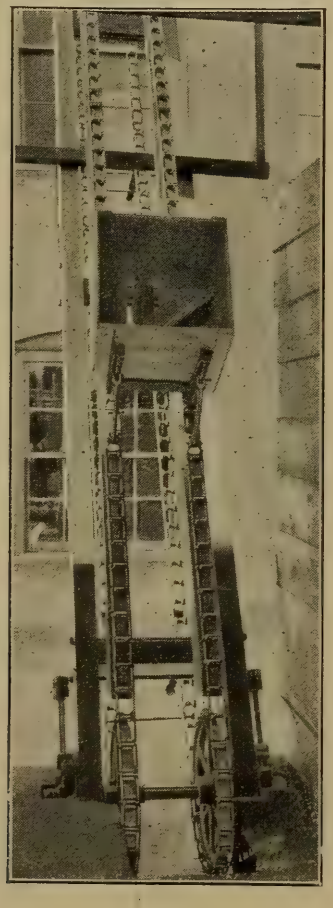
bolted to the frame. These bearings are provided with an exterior hood, or cover, which is easily removable to allow for adjustment and to exclude dust and grit.

The valve, which is of the piston type, governs the steam distribution under the control of a sensitive shaft governor. It should also be mentioned that this valve motion gives practically a constant lead at all cut-offs. Grease and oil cups on all the pins of the governor and valve gear reduce the friction at these parts and contribute largely to smooth, steady action.

The well-known automatic system of oiling by means of running the engine with a bath of lubricant in the bed has been most successfully applied to this type of vertical engine, so that the crank-pin, guides, and ring-oiling main bearings receive a copious supply of lubricant. All other bearing surfaces not cared for in this way are furnished with large sight-feed oil cups. The removable side plates enclose the working parts so as to afford a dust proof and oil-tight construction, yet allowing of ready access for adjustment. Careful design, high grade of workmanship and materials, coupled with copious lubrication and close regulation, are some of the essential features of this compact set.

Box and Barrel Elevators

THE empty box elevator shown in Fig. 1, on this page, is in use by the Scott Paper Company, of Philadelphia. The economic handling and disposition of empty packing cases or other empty receptacles often presents most vexatious problems. Being light in weight, they usually come in lots of large compass, loads of " bulk



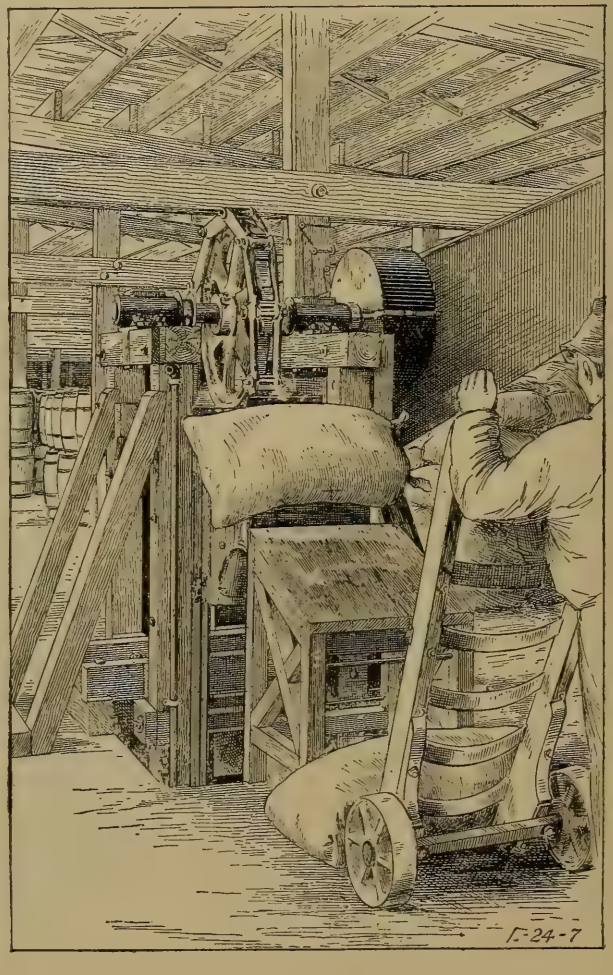


FIG. 1 FIG. 2

BOX AND BARREL ELEVATORS, MADE BY THE LINK BELT ENGINEERING COMPANY, NICETOWN, PHILADELPHIA, PA.

alone." To get them out of the way and accessibly stored with all possible expedition is not only desirable, but sometimes imperative. Often more labour and more annoyance is occasioned in accomplishing this than by the handling required after packing.

The device shown represents but another utilisation of the numerous labour-saving appliances of what is familiarly known as link belting, and was built by the Link Belt Engineering Company, of Nicetown, Philadelphia. A double strand of link belting is employed, and at intervals of 5 feet, as is plainly shown in Fig. 1, a straight arm is attached, one to each "belt." The machine is mounted in a wooden frame, and carries empty boxes from the ground to the upper floor of the warehouse at the rate of twelve per minute.

Another application of the same principle arranged for much heavier work is the barrel and sack elevator, shown in Fig. 2. This machine is provided with automatic arms which permit of barrels and sacks being elevated and gently delivered to any floor, while simultaneously others are being carried down on the opposite side. The view shown is from a photograph of the Lehigh Valley Railroad Company's Jersey City freight house. The machine has 37-foot centres, and uses heavy malleable iron chains with carrier arms attached every ten feet. The machine is provided with an adjustable stop, so arranged that the barrels are discharged at the proper height to be rolled away on the floor, or the sacks for convenient removal by hand trucks. The head is driven by worm gearing encased in a housing, and the worm runs in a bath of oil.

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New Trade Catalogues

"CARBONISING COATING" is the name of a protecting covering for iron and steel which is treated of in an interesting illustrated pamphlet issued by the Goheen Manufacturing Company, of Canton, Ohio, the illustrations, of which there is a goodly collection, showing different structures,—bridges, ore-docks, railway depots, tall hotel buildings, gasometers, and others which have been treated with this preparation, and with which most excellent results are said to have been achieved. The illustrations and the testimonials accompanying them are supposed to tell their own story, and they do it very well.

Marine engines of all kinds are illustrated and described in a neatly gotten-up catalogue issued a short time ago by the Marine Iron Works, of Chicago. There are various types of simple engines, fore-and-aft compounds, both double and triple-cylinder, vertical tandem compounds, stern paddle-wheel engines, and others, besides which a number of pages of the catalogue are devoted to different types of marine boilers, both vertical and horizontal, and water-tube. Steamboat accessories also come in for a fair share of attention,—steam whistles, propeller wheels, steering wheels, etc.

Hydraulic bending machinery of various kinds is illustrated and described in a new catalogue by the Watson-Stillman Company, of New York. Both pictures and data serve their purpose excellently, clearly setting forth the merits of the apparatus under consideration.

Francis H. Richards, of New York, the well-known patent expert, has issued a pamphlet setting forth the facilities of the establishment organised by him for carrying on all kinds of work, theoretical, practical, and legal, relating to inventions and patents. The booklet is illustrated in an interesting way with pictures of the various departments of Mr. Richards' establishment, showing the exceptional facilities which he has at his command for this particular kind of work.

Telpherage, which is another name for the automatic transportation of materials by electricity, either overhead, upon the surface, or underground, is treated of in a couple of interesting little pamphlets brought out by the United States Telpherage Company, of New York. A large number of illustrations are given, together with brief descriptive data.

"A Machine Shop Ideal" is the title

of a booklet brought out by what appears to be a combination of several prominent machine-tool builders, each of whom has in it illustrations and descriptive particulars of at least one of his representative types of tools. There is, for example, a lathe built by the Lodge & Shipley Machine Tool Company; a shaping machine built by the Cincinnati Shaper Company; two types of radial drills by the Bickford Drill & Tool Company; an upright drill by the Cincinnati Machine Tool Company; a planer by the Cincinnati Planer Company, and a universal milling machine from the shops of the Cincinnati Milling Machine Company, all of Cincinnati, Ohio. The catalogue directs attention to the fact that this is an age of specialisation, and that, therefore, the various special tools presented in the pamphlet ought to be found profitable ones to install in an up-to-date shop.

The A. A. Griffing Iron Company, of Jersey City, N. J., have issued a neat little folder devoted to their Bundy steam traps and separators. The company say in it that if they had the saving effected by the use of these appliances for a single year they might emulate Mr. Carnegie in his work of endowing colleges and building libraries, and it is this also which has prompted them to adorn the folder with a very well-executed portrait of Mr. Carnegie.

The Joseph Dixon Crucible Company, of Jersey City, issue a little price list of graphite brushes which they make for electric motors and generators, and incidentally take the opportunity which that little pamhlet affords of pointing out some of the advantages which graphite brushes have for this service.

The Edson Manufacturing Company, of Boston, are sending out an illustrated little circular devoted to their prospecting and mining outfit, the main feature of which is a powerful combination lift and force pump. It is said to be easily dismounted, simple in construction, and particularly well suited to take care of situations where there is either a super-abundance or a scarcity of water.

The Hancock inspirator in its various forms is presented in an attractive catalogue just issued by the Hancock Inspirator Company, of New York and Boston. There is a profusion of illustrations and all the particulars that prospective purchasers are likely to want. A couple of pages of the catalogue are devoted also to what is known as the Hancock shaking grate with water-tubes.

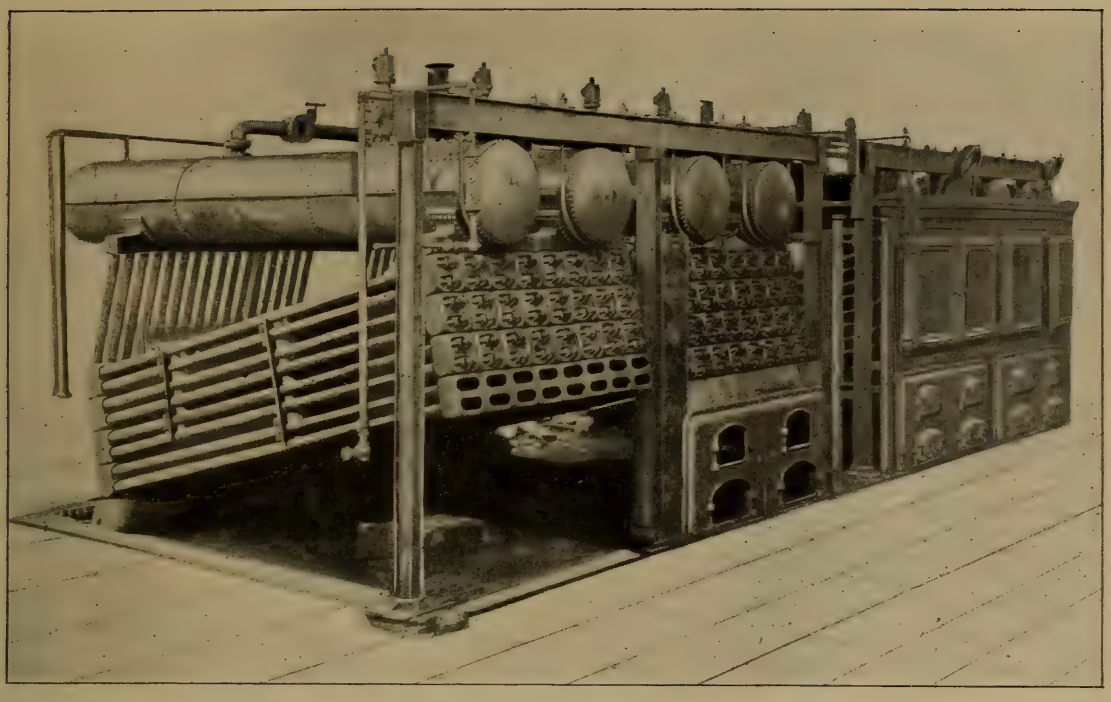
The American Steel and Wire Company, Chicago, is sending out a small pamphlet giving a list of the various products made by them. It is comprehensive in detail only to the extent necessary to give a clear idea of what the company turn out, but enough is shown to indicate the general lines. Even as it is, however, the list is of almost bewildering length.

Seamless, cold-drawn steel tubing forms the subject of an attractive little price list of the Shelby Steel Tube Company, of Cleveland, Ohio. Steel tubes of this kind are now in such general use for boilers that some of the particulars given of them in this booklet are well worth reading.

The United States Metallic Packing Company, of Philadelphia, set forth the particular features of their packings for marine and stationary engines in an attractive little catalogue. Illustrations are given in it, and prices as well.

Asbestos, in various forms, is presented in a new little pamphlet of the H. W. Johns Manufacturing Company, of New York. It is admirably suggestive of the various good uses to which this material may be applied with good results

A new catalogue of machine tools for working plates, bars, and structural shapes has been issued by the Hilles & Jones Company, of Wilmington, Del. It is made up practically altogether of illustrations which substantially speak for themselves. They include punches and shears, coping machines, bending and straightening machines, bending rolls, and other tools of similar character.



THE CALDWELL WATER-TUBE BOILER. MADE BY MESSRS. JAMES BEGGS & CO., NEW YORK

are made in a variety of styles and sizes so as to be suitable for any location. They are graceful in appearance, and can be finished in colors to correspond with prevailing decorations. The standard finish of the motor and base is black japan with gilt stripes. The fan blades and guard are polished brass.

A successful and economical exhaust fan is made by mounting a 12-inch Lundell fan, as shown in the annexed illustration. Placed in the upper part of a window, a good circulation of air is obtained. This application of small fans can be made to good advantage in machine shops, offices, factories, toilet rooms, etc. The Lundell fans are manufactured by the Sprague Electric Company, of New York.

The Caldwell Boiler

MESSRS. HAHNE & CO., of Newark, N. J., are building one of the largest new department stores in New Jersey, and the power equipment required for such a building must necessarily be extensive and of the very best. Mr. G. Starrett, of the firm of Thompson & Starrett, contractors, New York City, is the architect for this building, Messrs. Clinton & Russell being consulting architects. The steam heating engineers and contractors for the work are Messrs. Wells & Newton, of New York City. One of the important details of such a plant is the boilers, and these are of well-known Caldwell water-tube type, made by Messrs. James Beggs & Co., No. 9 Dey Street, New York City. They are very well illustrated in the cut on this page. The plant consists of four 250-H. P. boilers in two batteries. Each boiler is built for a working pressure of 150 pounds per square inch.

The special features in the construction of this boiler are that each header is composed of a square box, connected by four 4-inch tubes, expanded in the headers through the hand-hole openings. These openings are of such a size that one hand hole plate covers two tubes, and the joint is made on the inside of the header with an ordinary old-fashioned gasket. This construction reduces by one-half the number of parts which are generally required in the ordinary type of water-tube boiler and facilitates the opening of the boilers for inspection and cleaning. The hand-hole plate joints being on the inside of the header, dispense entirely with all

the strain on the bolt and bail holding a hand-hole plate in place, as the pressure, being against the inside of the plate, has a tendency to make this tight joint in proportion to the pressure; in other words, the higher the pressure the tighter the joint. All the header castings, with one exception, referred to below, are interchangeable, and are connected one on top of the other by means of two 4-inch nipples for each pair of headers. These nipples are expanded and flared over inside, thus making any column of headers flexible to a considerable extent.

The rear upper header is so arranged that access is obtained to the vertical down-takes from the exterior. It is not necessary, therefore, to go into the drums to clean these tubes; every tube in the boiler can be cleaned from the outside. This is a marked feature in the construction of the Caldwell boiler.

New Trade Catalogues

In the department of machine tools there are four new catalogues, two of them being very elaborate in point of illustration, and devoted to the tools of the Gisholt Machine Company, of Madison, Wis.; indeed, the interests of the well-known Gisholt turret lathe are well taken care of in these publications. One of the other catalogues is that of the Warner & Swasey Company, of Cleveland, Ohio, and deals with their hollow, hexagon turret lathe. The last is a grinding machine catalogue brought out by the Diamond Machine Company, of Providence, R. I. It is very profusely illustrated, and affords a series of object lessons in the development of this class of machinery.

Boring and turning mills are presented in still another catalogue by the Betts Machine Company, of Wilmington, Del. A large number of finely executed illustrations are given, together with the usual descriptive particulars.

Still another Westinghouse catalogue is that of the Westinghouse Electric and Manufacturing Company, devoted to electric mine locomotives. It is admirably illustrated, and makes a desirable addition to mine locomotive literature.

High-grade, spherical, steel-clad motors and dynamos form the subject matter of a neat little pamphlet brought out by the Browning Manufacturing Company, of Milwaukee, Wis. The motors shown range from one-twelfth horsepower upward, and are very business-like in appearance.

"Mining Machinery" forms the title of a new catalogue brought out by the E. P. Allis Company. It is specially devoted to concentrating machinery, mills, and appliances, and, in addition to the text, contains a large number of well-executed engravings.

Ice making and refrigerating machinery is taken up in a new catalogue of the York Manufacturing Company, of York, Pa. A large number of beautiful half-tone illustrations and plans and elevations of different forms of the York machinery are given, and help to admirably set forth its distinctive features.

"The Cause of Foaming in Locomotive Boilers" is the title of a neat booklet published by the Industrial Water Company, of New York City. It comprises virtually three articles on the subject which originally appeared in the *Railroad Gazette*, the end of which really is to emphasise the importance of water-softening and purifying processes. While it thus serves to direct attention to the work of the Industrial Water Company in a business way, it has all the merits of a little treatise on the subject of water purification, presenting the subject in an unprejudiced way.

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